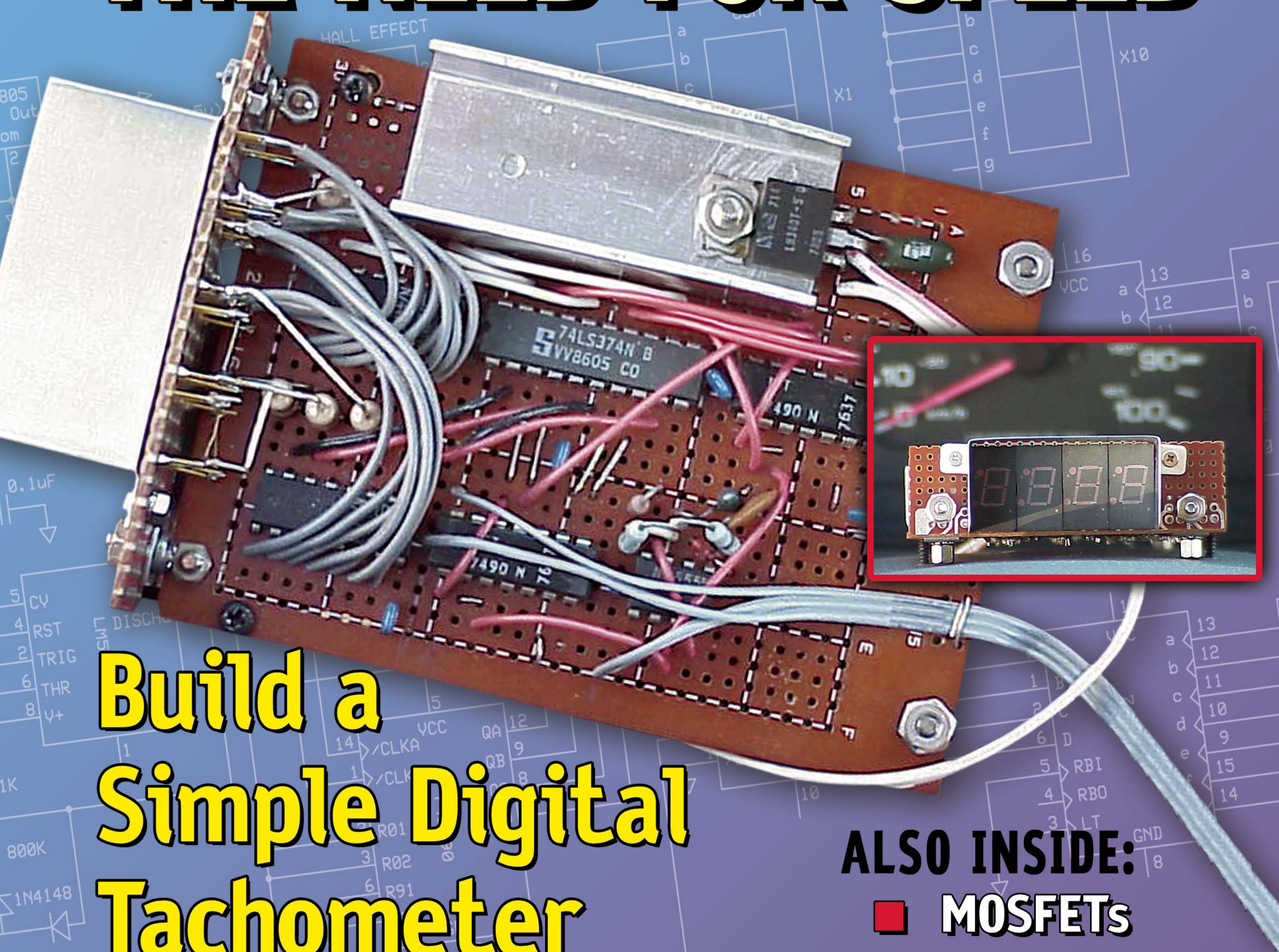
■ ROBOTICS ■ MICROCONTROLLERS ■ COMPUTER CONTROL ■ SPACE

NUTS AND VOLTS

EVERYTHING FOR ELECTRONICS

www.nutsvolts.com
MAY 2006

THE NEED FOR SPEED



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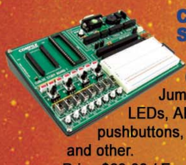

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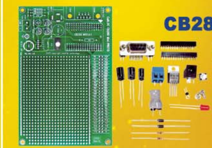

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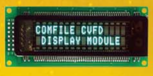

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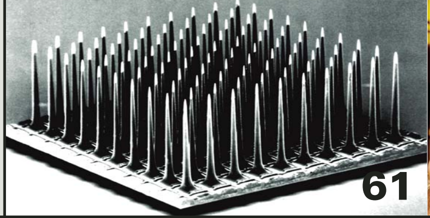
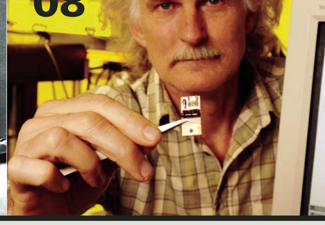
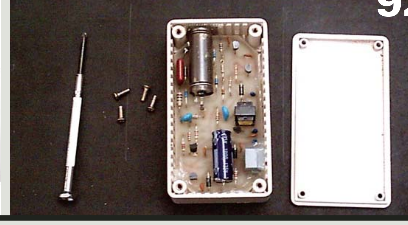




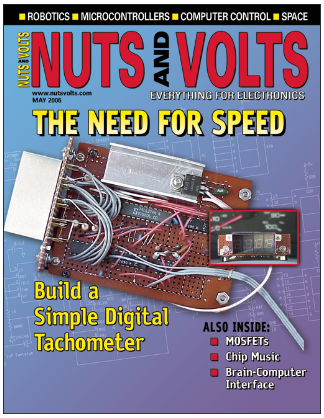


NUTS AND VOLTS

MAY 2006

PROJECTS and FEATURES

ON THE COVER ...



COLUMNS

DEPARTMENTS

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READER FEEDBACK

NUTS AND VOLTS
EVERYTHING FOR ELECTRONICS

PART HAS DEPARTED

Unfortunately between the writing and publishing of my Octal Logic Probe article in the April issue, Jameco has discontinued part #176532. If anyone can recommend an alternate source for MV50G or a suitable replacement LED with similar specifications (Green, T3/4, 300 mcd @ 20 mA, Radial leads) it would be appreciated.

Jim Brannan
Shop@ImpossibleEnterprises.com

MONEY MATTERS

I read the February Design Cycle on the 68HC908. Do I have to buy a Cyclone to see if I like using the 68HC908? The price of approx. $500 seems steep to see if I like a processor or not being just a hobbyist. Is there another way to go with the project that I could maybe afford? Thanks!

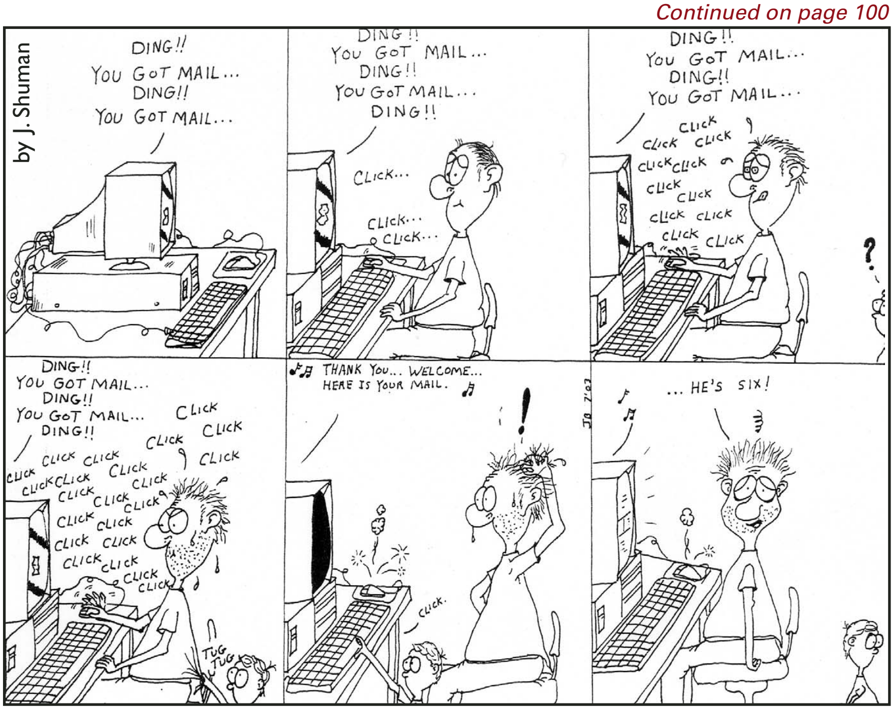
Dan Starkey

Response: *There are other less expensive ways to deal with a 68HC908. The minimum you can get away with commercially is about $200. You can use serial bootloader programs to load the 68HC908's Flash. However, you still need a hardware programmer to put the bootloader code into the device initially.*

The Cyclone PRO is a multi-purpose professional tool, which is reflected by the price. The $180 68HC908 MONO8 programming/debugging adapter you can get from Digi-Key is a barebones platform.

I did some walking around the web for you and found that the $180-$200 mark is about standard for any minimal MONO8 setup from various manufacturers. That's comparable with the Microchip MPLAB ICD 2 package, which goes for $149 bare. I also looked for some do-it-yourself MONO8 projects but found none. That's typical of Freescale stuff as most of the supporting hardware is more easily purchased than fabricated from scratch. Remember, Freescale came from Motorola and Motorola didn't care much about us hobbyists as most of their stuff was bought up by corporations like GM, Ford Motor Company, and Uncle Sam. Freescale is turning that around but the third party hardware support guys haven't quite caught up with the idea yet.

Continued on page 100



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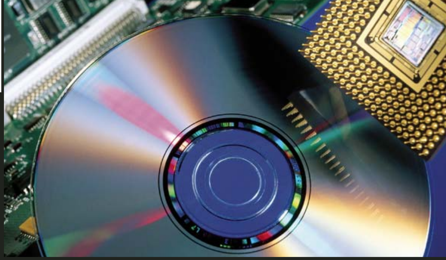


TECH KNOWLEDGEY 2006

EVENTS, ADVANCES, AND NEWS

■ BY JEFF ECKERT

ADVANCED TECHNOLOGY

NEW CIRCUITRY BASED ON GRAPHITE

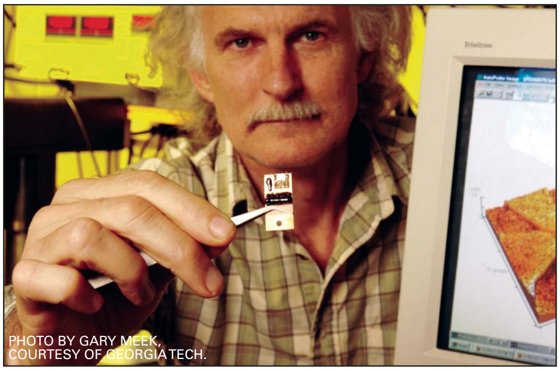


PHOTO BY GARY MEEK, COURTESY OF GEORGIA TECH.

■ Professor Walt de Heer holds a proof-of-principle device constructed of graphene.

If some researchers at the Georgia Institute of Technology (www.gatech.edu) and the Centre National de la Recherche Scientifique (www.cnrs.fr) in France have it right, we could someday be building electronic devices that are based on common graphite rather than silicon. Using thin layers of graphite (known as graphene), Prof. Walt de Heer and associates have demonstrated some proof-of-principle transistors, loop devices, and other circuitry.

Ultimately, they hope to use graphene layers less than 10 atoms thick as the basis for electronic systems that would manipulate electrons as waves rather than as particles, much like photonic systems control light waves. The technology is derived from that of carbon nanotubes, which have attracted a great deal of interest because they conduct electricity with virtually no resistance. This new material is simply a form of nanotubes consisting of graphene that has been rolled into a cylindrical shape.

"We expect to make devices of a kind that don't really have an analog in silicon-based electronics, so this is an entirely different way of looking at electronics," said Prof. de Heer. "Our ultimate goal is integrated electronic structures that work on diffraction of electrons rather than diffusion of electrons. This will allow the production of very small devices with very high efficiencies and low power consumption."

So far, they have built an all graphene planar field-effect transistor. The side-gated device produces a change in resistance through its channel when voltage is applied to the gate. However, this first device has a substantial current leak, which the team expects to eliminate with minor processing adjustments.

They have also built a working quantum interference device — a ring-shaped structure that would be useful in manipulating electronic waves. But don't expect large-scale manufacturing in the near future. According to the professor, "Building a new class of electronics based on graphene is going to be very difficult and require the efforts of many people."

METHOD MAY OPTIMIZE LIGHT-EMITTING SEMIS

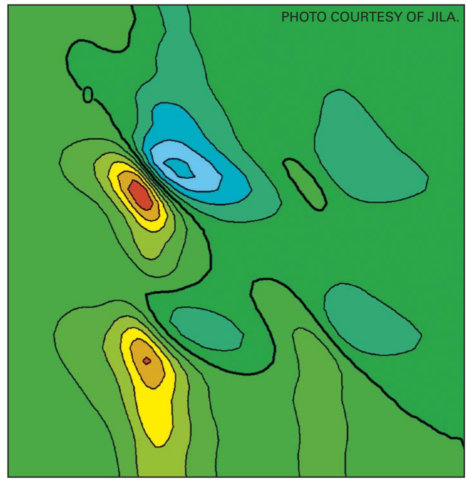


PHOTO COURTESY OF JILA.

■ This Rorschach-blot-like image shows the once-hidden behavior of semiconductors.

Physicists at JILA (jilawww.colorado.edu) — a joint institute of the National Institute of Standards and Technology (www.nist.gov) — have demonstrated an ultrafast laser technique for displaying previously hidden behavior in semiconductors. (In case you were wondering, JILA originally stood for "Joint Institute for Laboratory Astrophysics," but the institute now encompasses a much wider range of scientific endeavors, so JILA now officially doesn't stand for anything.)

In the JILA technique, a sample made of thin layers of gallium arsenide is hit with a continuous series of three near-infrared laser pulses lasting just 100 femtoseconds each. Trillions of excitons are thereby formed, which consist of "excited" electrons and the "holes" they leave behind as they jump to higher energy vibration patterns. By changing the timing of the laser pulses and analyzing the wave patterns of the light and exciton oscillations, the JILA scientists figured out how to produce and identify correlations between absorption and emission of light from the material.

As shown in the illustration, computer plots show how energy intensity (ranging from low in blue to high in red) varies as the excitons absorb laser light and emit energy at various frequencies. The pair of similar "butterflies" indicates that an exciton is absorbing and emitting energy in a predictable pattern. The method was originally developed by other researchers long ago for

probing couplings between spinning nuclei as an indicator of molecular structure, and it led to a Nobel prize; more recently, scientists have been trying to use it to study vibrations in chemical bonds.

This new application is aimed at producing more predictable designs of optoelectronic devices, including semiconductor lasers and white light-emitting diodes.

COMPUTERS AND NETWORKING

COMPUTERS NOW 60 YEARS OLD

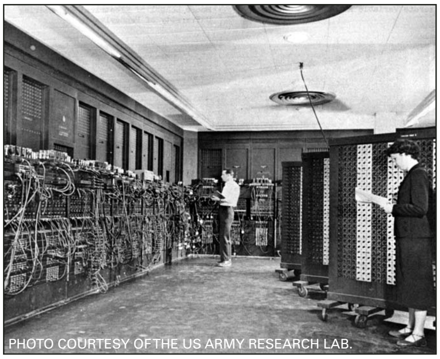


PHOTO COURTESY OF THE US ARMY RESEARCH LAB.

■ The original ENIAC.

In case you didn't notice, 2006 marks the 60th anniversary of the first electronic computer, the ENIAC (electronic numerical integrator and computer), invented by Dr. J. W. Mauchly and my favorite uncle, J. Presper Eckert, Jr., both of the Moore School of Electrical Engineering of the University of Pennsylvania (**www.upenn.edu**). (Just kidding — we're not related, as far as I know.)

It was officially introduced in February 1946. Built at a cost of about $400,000, ENIAC used nearly 18,000 vacuum tubes, weighed 30 tons, drew about 150 kW of power, and filled a 30-by-50 ft room. Its performance was originally described as "phenomenal," as it could perform a simple addition in only 1/5,000 of a second. But it could actually perform three-dimensional, second-order differential equations, not just simple arithmetic. And, contrary to popular mythology, it blew a tube only every two days or so.

The machine operated at a clock rate between 60 and 125 kHz, which was pretty impressive at the time, although its descendent, the UNIVAC, was considerably faster, at 2.25 MHz. For more information, you can visit the ENIAC Museum Online at **www.seas.upenn.edu/~museum** And if you want to take a look at the original press release from the War Department, just aim your browser at **americanhistory.si.edu/collections/comphist/pr1.pdf** and you can download it.

CPU COOLER ALLOWS OVERCLOCKING

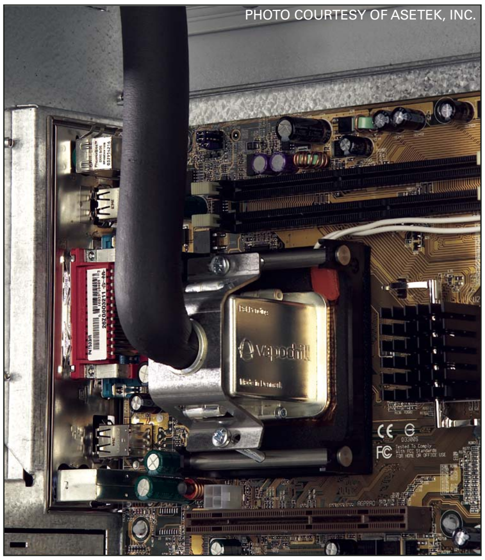


PHOTO COURTESY OF ASETEK, INC.

■ The VapoChill® cooling system allows CPUs to run up to 50% faster.

If you are something of a fanatic about getting the highest possible performance for your machine, you might want to consider installing a kit from Asetek, Inc. (**www.asetek.com**). This Danish company specializes in cooling systems, and it recently demonstrated a PC — which it calls the Dream Machine — that is based on a 3.8 GHz Pentium 4 chip, but actually runs at 5.46 GHz.

This overclocking is achieved via the company's VapoChill LightSpeed system, which keeps the processor running at a cool -33°C. It uses a compressor to accomplish the task, which is said to be 10 times as efficient as water cooling and 50 times better than air cooling. The CPU mounting kit is said to be easy to install (with "easy" appearing to be a relative term), and it supports both AMD K8 and Intel P4 chips. The unit will set you back about $820, though, so it isn't for the faint of heart.

FREE LAPTOP REPAIR GUIDES

Started a year ago as a site combining the do-it-yourself ethic with computing, Repair4Laptop (**repair4laptop.org**) recently announced that its collection of user-submitted manuals has grown beyond 600, ranging from step-by-step instructions for popular repairs to more exotic laptop modifications.

Since notebook computers are difficult, expensive, and time-consuming to repair, the site fills a niche as both a knowledge-base and a community. It provides free access to a variety of resources for repairing, upgrading, modifying, and servicing laptops and notebook computers, arranged by manufacturer and part, including keyboards, hard drives, optical drives, displays, RAM, CPUs, batteries, and others.

PERSONAL NAVIGATION SYSTEM IS FREE *(Almost)*

Earthcomber, touted as the "ultimate personal navigator," has

■ The Earthcomber navigation system is now available for Windows Mobile-based handhelds.

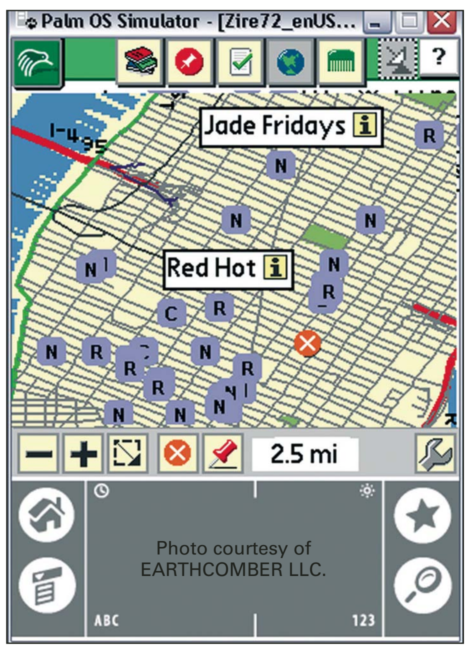


Photo courtesy of EARTHCOMBER LLC.

been around since 2004 for the Palm OS but now is available for Windows Mobile-based devices. It is basically a set of programs for handheld digital assistants and smart phones that allows you to locate yourself on a map anywhere in the US and then identify whatever you are seeking (e.g., stores, parks, museums, bars, restaurants) in that particular area and even get driving directions.

The product is billed by the company as being free, and for the most part it is. The program itself and maps, "look lists," and "community" feature cost nothing. However, if you want to upgrade it with digital guidebooks on specialized subjects, you will have to pay up to about $20 for each brand-name Spot Guide™. Details are available at **www.earthcomber.com**

CIRCUITS AND DEVICES

REDUCING SPLICES INTRODUCED

If you work with high-voltage equipment (600 V to 35 kV), you may be interested in the newly introduced Color-Keyed® cast-copper reducing splices from Thomas & Betts (**www.tnb.com**). Even though they are designed for joining conductors of different diameters, the splices themselves feature a constant outer diameter, which allows crimping both ends with the same tool or die, thus reducing installation time. It also makes it easier to insulate the splices with heat-shrink wrap or clamshell covers. Applications include telecommunications for both the inside office and outside plant, as well as industrial maintenance, repair, and operations and commercial contracting.

NONCONTACT IR THERMOMETER INTRODUCED

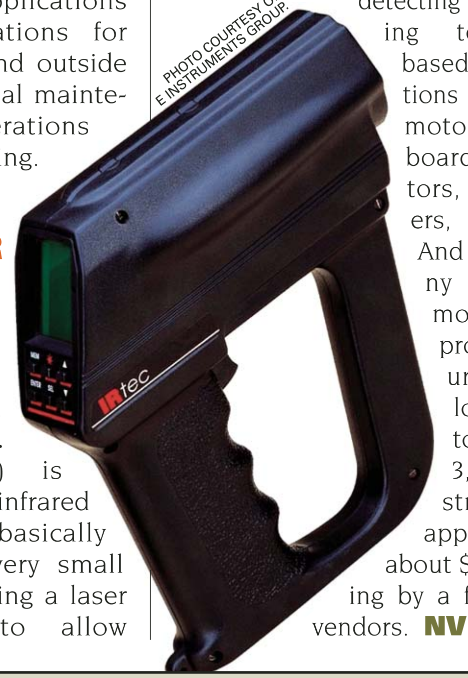


PHOTO COURTESY OF E INSTRUMENTS GROUP.

■ The IRtec P1300 infrared thermometer.

The latest offering from E Instruments (**www.einstrumentsgroup.com**) is the P1300 — a portable infrared thermometer. It is basically designed to measure very small targets at a distance, using a laser pinpointing system to allow measurements in tough-to-access areas.

Major features include: ±0.01 percent temperature stability; actual maximum, average, minimum, and deltaT measurements; a 500-record memory; and programmable alarms. It operates in the temperature range of 570 to 2,370° F, so it probably won't be of much use in small electronics.

However, it can be helpful in detecting and preventing temperature-based malfunctions on bearings, motors, switchboards, conductors, transformers, and so on. And the company sells other models that provide measurements as low as -20° F to as high as 3,630° F. The street price appears to be about $2,000, judging by a few Internet vendors. **NV**

INDUSTRY AND THE PROFESSION

EARLY SOUND RECORDINGS AVAILABLE

The library at the University of California, Santa Barbara (**www.ucsb.edu**) recently opened up a website that offers thousands of digitized Edison cylinder recordings, making a little-known era of recorded sound (the mid 1890s to the mid 1920s) broadly accessible to scholars and the public for the first time. The height of the cylinder record's popularity was over 90 years ago and, unlike 78-rpm and LP recordings, they have not been widely reissued in modern formats.

With funding from the Institute of Museum and Library Services — a federal agency — the library has created a new and growing digital collection of more than 6,000 cylinder recordings from its Department of Special Collections. The new online collection allows users to download digitized versions of thousands of cylinder recordings to their computers and MP3 players or to listen to the recordings online.

You can download streams of programs in groups arranged around a theme, including cakewalks and rags, German comic cylinders, American Vaudeville, early black artists and composers, operatic cylinders, pioneers of audio theater, and historical speeches. All you have to do is visit **http://cylinders.library.ucsb.edu** Best of all, it's free.

■ Early recordings made on Edison cylinders are available for MP3 players.

■ BY CHUCK HELLEBUYCK

USING THE MICROCHIP PIC TIMERS

ONE OF THE MORE POPULAR REQUESTS I've received from *Nuts & Volts* readers is to demonstrate how to use the Microchip PIC timers. I know when I started with PICs it was one of the areas I wanted to learn, and it was also one of the more confusing peripherals to get working properly. They're not difficult to understand, but they have so many options that the beginner gets overwhelmed.

For this article, I'll explain timers and then use the Timer 1 peripheral to form an accurate one-second time base. This could be considered an advanced project so don't be too hard on yourself if it takes a while to completely understand it.

WHAT IS A TIMER?

Inside almost every Microchip PIC is a timer peripheral. In some PICs, such as the PIC16F876A I've used in previous articles, there are three timers. But what is a timer, what does it do, and how do we use in with PICBasic Pro?

The so-called "Timer" inside a Microchip PIC is just a binary counter circuit fed by a controlled-frequency clock source. For all you former TTL/CMOS users out there, think of it as an eight- or 16-bit binary ripple counter chip built into the PIC. In other words, it's not a stop watch or clock outputting minutes, seconds, or tenths of seconds to display somewhere. It's just a binary counter with a time base supplied from the internal PIC clock and driven by the external resonator or crystal (see Figure 1). Therefore, we can use the value obtained from the timer peripherals in the PIC to calculate various functions, such as a time base, to determine when to change an output from a high state to low or low state to high.

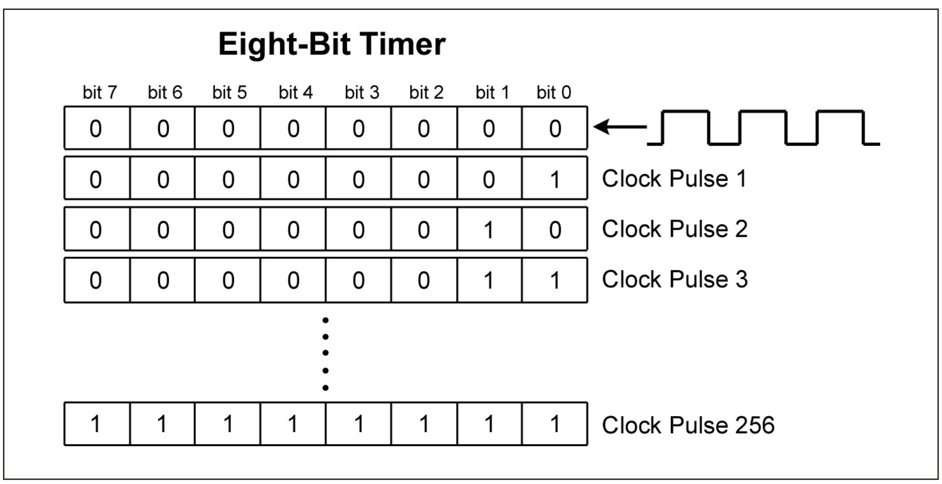
Timers can do more than serve as a time base; they can also be used as an asynchronous counter controlled from an external signal that has no connection to the internal clock. I'll cover this later, but these sorts of added capabilities the timers have are what create confusion for the beginner. I just want you to understand that a PIC timer is a binary counter that runs by itself in parallel with your main program. They can also interrupt your main program (if you set that up), and they can be read or reset at anytime from your main program.

One more very important point the beginner needs to know: the internal clock that feeds the timers and your main program is the external resonator or crystal frequency divided by four. For example, if you have your PIC running with a 4 MHz resonator, the internal clock feeding the program counter and timers is running at 1 MHz. You need to understand this to properly set up the internal timers.

TIMER CHOICES

There are three different types of PIC timers with three different names: TMR0, TMR1, and TMR2. Two are eight-bit wide (TMR0 and TMR2), and one is 16-bit wide (TMR1). Because timers are binary counters, the eight-bit timers can count from 0 to 255 (binary 0 to binary 11111111), and the 16-bit timer can count from 0 to 65535 (binary 0 to binary 1111111111111111).

The three timers have different features that make them unique and useful for different applications.



■ FIGURE 1. The PIC timers are binary counters driven by the PIC's internal clock.

TMR0

- Eight-bit timer
- Readable and writeable as one byte
- Can be fed from internal clock or external input pin (A4)
- Can be set to create a hardware interrupt at overflow (255 > 0)
- Can use an eight-bit prescaler 1:2 to 1:256
- Is rising- or falling-edge selectable for external input

TMR1

- 16-bit timer
- Readable and writeable as two bytes
- Can be fed from internal clock or external clock crystal
- Can be set to create a hardware interrupt at overflow (65535 > 0)
- Can use a four-bit prescaler 1:2 to 1:8

TMR2

- Eight-bit timer
- Readable and writeable as one byte
- Writeable comparison byte size register
- Only fed from internal clock
- Constantly compared to secondary presettable binary value
- Can have 1:1, 1:4, 1:16 prescaler or 1:1, 1:2, 1:3 to 1:16 postscaler
- Output can drive synchronous port
- Can be set to trigger a hardware interrupt each time it matches a preset value

All three can be fed from the internal PIC clock, but TMR0 can also be fed from an external input pin. This allows TMR0 to act as either an event counter or a timer. The 16-bit TMR1 can be controlled by an external crystal separate from the internal PIC clock or from an external input, making it a 16-bit counter. This offers the opportunity to control TMR1 externally from a slower clock source such as a digital-watch crystal or a digital-counter source. TMR2 can only run from the internal PIC clock but, like a time-elapse timer, can be automatically set to constantly check whether it matches a preset value.

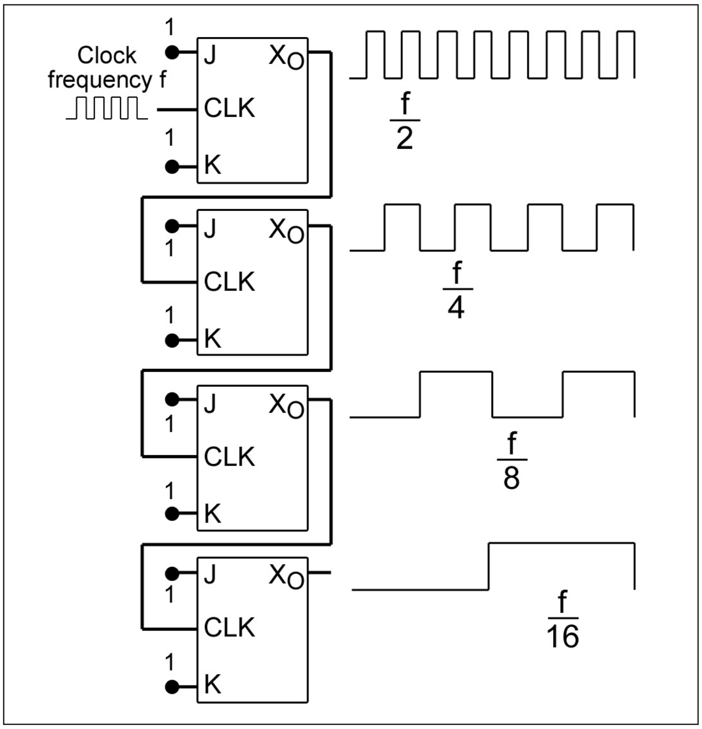
Figure 2 shows the features of the three timers along with the control bits to set up these features.

Each of the timers has a register for its count value. These values can be read or modified from within your code. TMR1, which is 16-bits wide, has two registers, TMR1H and TMR1L, because the PIC has an eight-bit data bus. These are the high-byte and low-byte values and, combined, they form a word. To access this timer's value you have to read each register separately and then combine them into a word variable.

PICBasic Pro makes it easy to read from and write to these registers directly because it has reserved the register names as keywords in its syntax. For example, to preset TMR0 to 56 so it will overflow on the 200th pulse rather than 256, you just add the

FEATURES	TMR0	TMR1	TMR2
Size	Eight-Bit	16-Bit	Eight-Bit
Prescaler	OPTION_REG.3 - 0 %1xxx = 1:1 %0000 = 1:2 %0001 = 1:4 : %0111 = 1:256	T1CON.5 -T1CON.4 %00 = 1:1 %01 = 1:2 %10 = 1:4 %11 = 1:16	T2CON.1 -T2CON.0 %00 = 1 %01 = 4 %1x = 16
Postscaler	Not Available	Not Available	T2CON.6 - 3 %0000 = 1:1 : %1111 = 1:16
Interrupt Enable Bit	INTCON.5	PIE1.0 and INTCON.6	PIE1.1 and INTCON.6
Interrupt Flag	INTCON.2	PIR.0	PIR.1
Internal Clock	Fosc/4 Selected by OPTION_REG.5 = 0	Fosc/4 Selected by T1CON.1 = 0	Fosc/4 (Only Option)
External Crystal/Resonator	Not Available	Crystal or Resonator connected between C0 and C1 pins Selected by T1CON.1 = 1 and T1CON.3 = 1 Sync external with internal clock selected by T1CON.2 0 = Synchronize 1 = Do Not Sync	Not Available
Counter Mode or External Clock Mode	Pulse signal connected to TOCKI Pin Selected by OPTION_REG.5 = 1 Edge Select Bit for Incrementing: OPTION_REG.4 0 = Low to High 1 = High to Low	Pulse signal connected to C0 pin Selected by T1CON.1 = 1 and T1CON.3 = 1 Sync external with internal clock selected by T1CON.2 0 = Synchronize 1 = Do Not Sync	Not Available
On/Off Control	Not Available (Always on)	T1CON.0 0 = Off 1 = ON	T2CON.2 0 = Off 1 = ON
Timer Register Name(s)	TMR0	TMR1H - High Byte TMR1L - Low Byte	TMR2

■ FIGURE 2. Timer features and their control bits.



■ FIGURE 3. The PIC prescaler is a shift register with a software-selectable output position.

statement below to your code.

```
TMR0 = 56        ' Preset TMR0 to 56 or %00111000 binary
```

If you were running the TMR0 timer in counter mode and wanted to check its value in your main program loop, you could read it directly and store the value in a variable with the statements below.

```
countervalue var byte    ' Setup byte variable named
                         '  "countervalue"

countervalue = TMR0      ' Store TMR0 value in variable
                         '  countervalue
```

PRESCALER/POSTSCALER

As I mentioned earlier, timers also have a prescaler or postscaler attached to their input or output. Prescalers and postscalers are the same, except that one (prescaler) is at the input of the timer, and the other (postscaler) is at the output. A prescaler or postscaler is just a shift register with a software-selectable output position. Figure 3 shows what a section of a prescaler looks like.

You can make them output every second pulse, fourth pulse, eighth pulse, up to the 256th pulse (prescaler) or every first, second , third, up to the 16th pulse (postscaler). What these do is add a way to slow down the clock signal so the binary counter doesn't overflow or output a signal so quickly. In a PIC running with a 16 MHz external resonator, the internal clock feeding the timers would be running at 4 MHz. If you enable the TMR1 prescaler and set it to a 1:4 ratio, it will slow the timer clock down to 1 MHz while allowing the other timers and main program to still run at a 4 MHz rate.

The postscaler is only available on the TMR2 timer. TMR2 is constantly compared to a preset value. The postscaler can make the timer match that preset value more than once before outputting a signal. If the postscaler is set to 1:4, TMR2 has to hit the preset value and output a signal to the postscaler four times before the postscaler sends a signal to the main program. This may seem a little confusing, but after you use prescalers and postscalers a few times, they will become easy to understand.

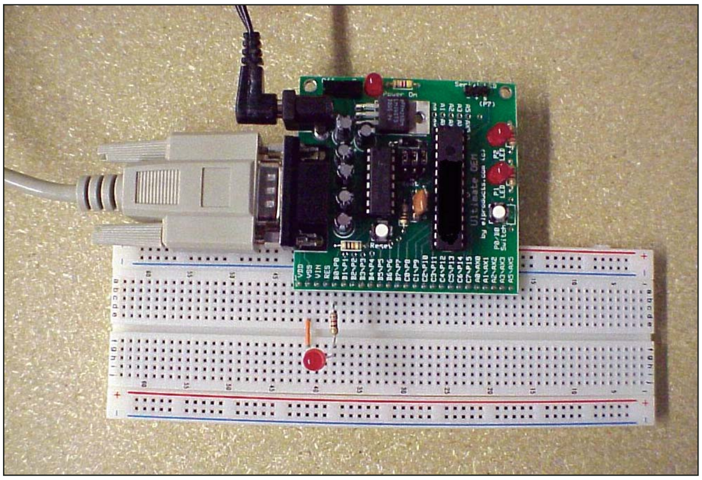
TIMER SETUP

All these options — prescaler, internal or external clock source, rising- or falling-edge transition, or any other option you want to change on the timers — are controlled by a few special function registers within the PIC. Each timer has its own set of registers that control its setup. I can't cover them all here, but I do reference them in Figure 2. If you read the PIC16F876A data sheet, check out the OPTION register, PIE register, PIR register, T1CON register, T2CON register, and INTCON register to see how these registers play a role in controlling the timers. In this month's project, I'll use the 16-bit TMR1 as a one-second time base. I'll show how to set up the TMR1 timer using the special function registers. I'll also introduce the use of the TMR1 interrupt to show how it can update the main program loop while running in the background.

TMR1 EXAMPLE

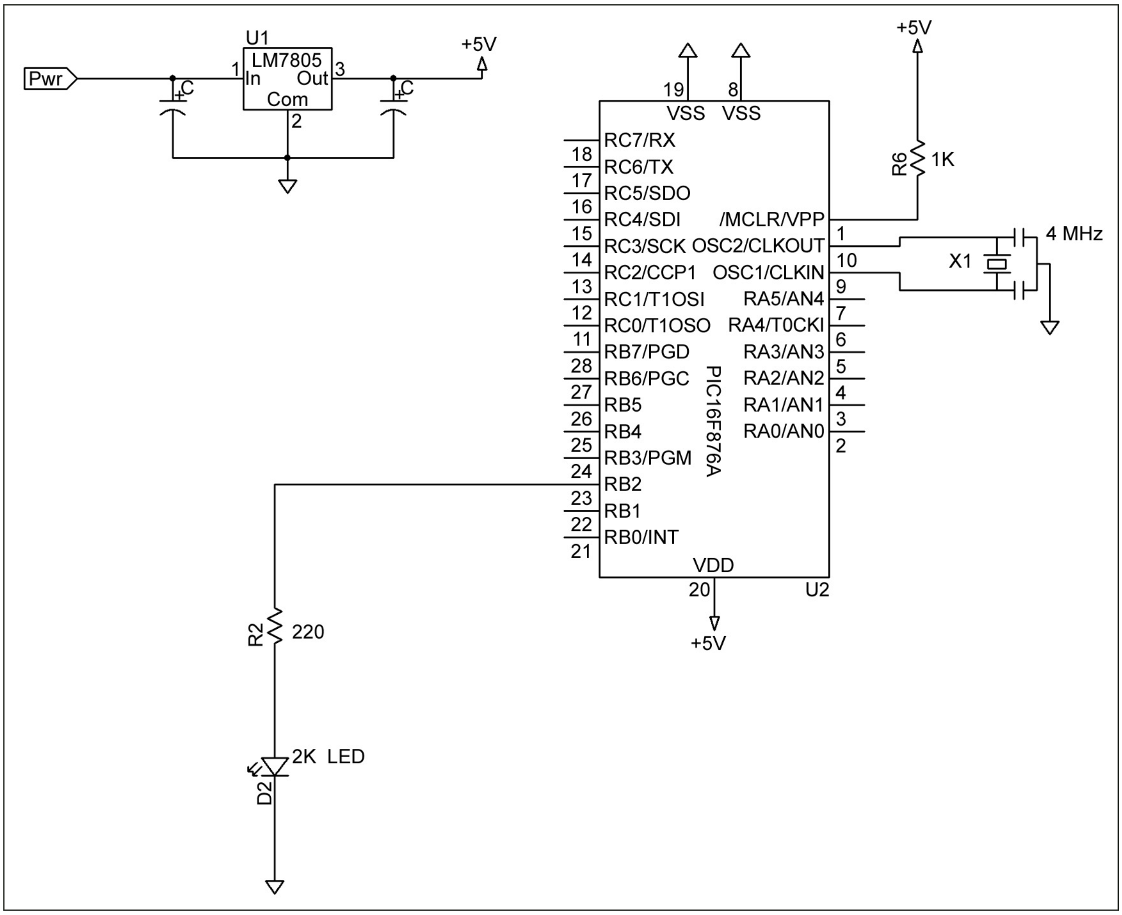
This project demonstrates how to use the 16-bit wide timer as an accurate time base. I didn't want to complicate this project, so I decided to do something simple: flash an LED at an accurate one-second rate. You can't get much simpler than that. This allows us to once again use the 31 command sample version of PICBasic Pro.

I also took a short cut in my hardware: I used one of my Ultimate OEM modules. The Ultimate OEM is a PIC16F876A development module with a lot of features



■ FIGURE 4. The hardware setup for this month's project.

■ FIGURE 5. Schematic for this month's project.



built in, including the basics such as resonator socket, reset switch, MCLR resistor, five-volt regulator, and On/Off switch. It also has a power port and RS232 connection for serial communication and bootloader programming capability (which I will discuss in a later article). You don't need this module to do the project, but it does make development easier. I use it in all my projects and I designed it to work with the projects in my book *Programming PIC Microcontrollers with PICBasic*. It also converts to an Atom module with just a chip change, which makes it easy to write Atom and PICBasic Pro code for the same hardware setup. The hardware for this month's project is shown in Figure 4.

TMR1 SETUP

The 16-bit Timer1 counts from 0 to 65535, incrementing once on every internal clock pulse. It then overflows and resets back to 0 on the next pulse. When it overflows, it sets the TMR1IF (Timer1 Interrupt Overflow Flag) bit on the PIR1 register of the PIC. When this bit is set, it triggers an interrupt if you have interrupts turned on in software. The software section will describe how to set up interrupts.

For this project, I'll be running the PIC with a 20 MHz (20,000,000 pulses/second) resonator clock signal rather than the typical 4 MHz. I did this to show how to use the prescaler. The external clock signal gets divided by four inside the PIC chip to form the internal clock pulse that drives the timers. The project will further divide that signal by eight using the Timer1 prescaler. If you were to calculate this out, you would see that the Timer1 overflows every 0.104856 seconds:

$$\frac{65535}{20{,}000{,}000 \text{ Pulses/Second } (1/4)\ (1/8)} = 0.104856 \text{ seconds}$$

We want it to overflow on an even number such as 0.10 seconds (100 ms). If the Timer1 overflowed every 62500 pulses, it would be a perfect 100 ms time base. We can make this happen by presetting the Timer1 to 3035 (65535 – 62500 = 3035) or $0BDB hex. Then we can track the number of overflows, and when 10 have occurred, we know that one second has passed. With that information, the program can change the state of an LED from OFF to ON or ON to OFF at an accurate rate of once per second (1 Hz). The adjusted calculation is shown below.

$$\frac{62500}{20{,}000{,}000 \text{ Pulses/Second } (1/4)\ (1/8)} = 0.10 \text{ seconds}$$

HARDWARE SETUP

The hardware schematic is shown in Figure 5. Even though I used my Ultimate OEM module, I show the schematic as raw PIC so you can build this yourself without the Ultimate. The PIC used is the PIC16F876A, which is I/O overkill for flashing an LED, but a lot of readers have this chip already, and many of the smaller I/O PICs don't have a TMR1 on-board.

The schematic shows the PIC16F876A with a 20 MHz resonator and MCLR resistor connected. I show the LED anode connected to the B0 pin through a 220 ohm resistor and the cathode tied to ground. The PIC gets its 5V from a 7805 regulator circuit.

SOFTWARE

The code shown in Listing 1 is not that long or complicated once you break it down. Remember, we are doing two advanced functions here: using the Timer1 and using interrupts.

HOW IT WORKS

The program starts off with the specific DEFINEs required. This defines the bootloader self programming setup that the Ultimate OEM module has built in. I know a few readers are using bootloader modules so this is there for them. Since most readers are programming it into a blank PIC using a PIC programmer, you don't need this line so I commented it out by putting an apostrophe in front of it. PICBasic Pro will treat it as a comment line and ignore it during compile time.

```
' DEFINE LOADER_USED 1     ' This command line for Ultimate
                           ' OEM only
```

The next DEFINE establishes the oscillator frequency. PICBasic Pro defaults to 4 MHz. Therefore, we must adjust the time-based commands for the higher frequency. PICBasic Pro automatically adjusts for the higher speed when we add this DEFINE:

```
DEFINE OSC 20
```

We establish only one variable for this simple program. It's called "counter." It will store how many times the program interrupted so we can see when we have reached 10 interrupts (one second).

```
counter var byte        'Establish a byte size variable
```

The program has to initialize Timer1 to 3035 decimal, and we do that by writing directly to the Timer1 registers, TMR1H and TMR1L. You could use decimal numbers for this, but that would be confusing because TMR1H would have to be set to 11 and TMR1L to 219, and it's not obvious that these combine to form the word value 3035. You could use binary, setting all eight 1s or 0s in their proper order, but that's a lot of typing. This is where hexadecimal numbers are handy. You can use the Windows scientific calculator to easily convert 3035 decimal to $0BDB hexadecimal and then make TMR1H equal to the first two digits and TMR1L equal to the second two. That's what I did here. The dollar sign tells PICBasic Pro that the number is a hex value.

```
TMR1H = $0B             'Preset Timer 1 to 3035
TMR1L = $DB             '  using $0BDB hex
```

LISTING 1

```
' DEFINE LOADER_USED 1          ' This command line for Ultimate OEM only

DEFINE OSC 20                   'Set oscillator to 20 MHz
counter var byte                'Establish a byte size variable

TMR1H = $0B                     'Preset Timer 1 to 3035
TMR1L = $DB                     '  using $0BDB hex
T1CON = %00110001               'Timer1 on with 1:8 prescaler
PIE1 = %00000001                'Enable Timer1 Interrupt
INTCON = %11000000              'Enable interrupts
ON INTERRUPT GOTO mytimer       'Define interrupt handler

high 2                          'Initialize B2 LED to on
counter =0                      'Initialize counter to zero

main

if counter = 10 then            'Test for 10 interrupts
toggle 2                        '10 interrupts occurred so flip LED state
counter = 0                     'Reset counter variable
endif                           'End the If-Then command

goto main                       'Loop back to the Beginning

'*** This is where we go on and interrupt ***

disable                         'Prevent interrupts from occurring

mytimer:                        'Interrupt handler routine label
TMR1H = $0B                     'Preset Timer 1 to 3035 decimal
TMR1L = $DB                     '  using $0BDB hex
counter = counter +1            'Increment the timer overflow count
PIR1.0 = 0                      'Clear Timer1 overflow interrupt flag
resume                          'This is how we exit an interrupt
```

Next, we enter the special register setup commands. As mentioned, the PIC automatically divides the 20 MHz clock by four, but we need to set up the divide-by-eight prescaler. We do that by setting the proper bits in the T1CON register. Setting the fifth and sixth bits to "1" establishes the prescaler as 1:8. The first bit (bit 0 in the data sheet) turns the timer on (set to "1") or off (set to "0"). We turn it on here. As you can see, in this case, I used binary rather than decimal or hex (the "%" symbol indicates it's a binary number). Using binary makes it easy to check which bits are set and which are cleared. Each number system has its proper place in programming.

```
T1CON = %00110001     'Timer1 on with
                      ' 1:8 prescaler
```

Another register that needs to be set up is the PIE1 register. It controls peripherals such as Timer1 and Timer2. The first bit (bit 0) is the Timer1 interrupt enable bit. We need to set this to "1" to allow or enable the Timer1 overflow to cause an

interrupt to the main program loop. I use binary again here.

```
PIE1 = %00000001          'Enable Timer1 Interrupt
```

Interrupts in the PIC are controlled from a key register called the INTCON register. There are two bits in the INTCON that enable the Timer1 interrupt. The seventh bit (bit 6) is the PEIE bit that enables any interrupts set in the PIE1 register. The eighth bit (bit 7) is the GIE or Global Interrupt Enable bit that enables all interrupts. This is like a pecking order. All bits of these various registers have to be set for the Timer1 interrupt, but none of them work until the top bit (GIE) is set. This is the central control bit that makes it easy to turn on or turn off all interrupts. You'll see how PICBasic Pro also enables or disables interrupts in sections of code using a PICBasic Pro command. The bits are set, and easily seen, using a binary number.

```
INTCON = %11000000        'Enable interrupts
```

Finally, the label of where to jump to when the interrupt or overflow occurs is defined as "mytimer." Later, I'll explain what we do when the interrupt actually occurs at the "mytimer" label.

```
ON INTERRUPT GOTO mytimer       'Define interrupt handler
```

Before we get to the main loop, we start the LED in the ON state by setting PortB's bit 2 to a high value using the HIGH command. We also reset the "counter" variable to "0."

```
high 2                    'Initialize B2 LED to on
counter =0                'Initialize counter to zero
```

The main section of code starts with the label "main." This section is really simple. It checks whether the variable "counter" is equal to 10 yet. If it isn't, the program just loops back and does it again. If, however, the value is equal to 10, then we want to change the state of the LED, and we use the TOGGLE command to do that. TOGGLE just switches it from OFF to ON or from ON to OFF. Then we reset the "counter" variable to "0" and end the IF-THEN statement with the ENDIF command.

From there, we loop back to "main" to test "counter" again.

```
main

if counter = 10 then      'Test for 10 interrupts
toggle 2                  '10 interrupts occurred so flip
                          '  LED state
counter = 0               'Reset counter variable
endif                     'End the If-Then command

goto main                 'Loop back to the Beginning
```

The last section of code is the interrupt code and is separate from the main loop of code. When the interrupt occurs, the program will finish whatever command was being executed, then jump to the defined interrupt label, which is "mytimer" in this example. Note that I said the program will finish its command before jumping to the interrupt label. PICBasic Pro doesn't implement true hardware interrupts unless you write the interrupt routine in assembly and do some other advanced setup functions. Therefore, it offers two forms of interrupt: simple and complex. Simple works for most examples, and it works here. That's why I'm using it.

The simple interrupt method has one drawback and that is delay time of the commands. If you have a command such as PAUSE 5000 in your main loop and it receives an interrupt, the program will not jump to the interrupt service routine until the full five seconds of pause have occurred. Therefore, all commands should be short when you use interrupts. A FOR-NEXT loop of 5000 loops of PAUSE 1 would be a better way to achieve the same result because it allows quicker interrupt response. This time delay before the interrupt code starts running is known as interrupt latency. Interrupt latency is one drawback of programming in Basic vs. programming in assembly.

Before the "mytimer" label is the DISABLE command. This shuts off the Timer1 interrupt for any code below that command. This is necessary so the interrupt cannot occur while we are running the interrupt routine. If we allowed that, we could end up in a continuous loop of interrupts and never leave the interrupt routine. This is also why it is very important to make your interrupt routines short so we don't miss an interrupt while processing one.

```
disable                   'Prevent interrupts from
                          '  occurring
```

In the interrupt service routine (or handler), we do two things: reset Timer1 to 3035 and increment the "counter" variable. Remember, we check this variable to see if it equals 10 in the main loop, but we increment it in the interrupt service routine.

```
mytimer:                  'Interrupt handler routine label
TMR1H = $0B               'Preset Timer 1 to 3035 decimal
TMR1L = $DB               '  using $0BDB hex
counter = counter +1      'Increment the timer overflow
                          '  count
```

At the end of the interrupt routine, we need to reset the Timer1 overflow interrupt flag (TMR1IF) so we don't instantly jump back into an interrupt condition. We do that by directly setting the PIR1 bit 0 to "0." We follow this with the RESUME command, which is required by PICBasic Pro. This jumps the program back to the main loop where it was interrupted. A GOTO command or RETURN command won't work here. Interrupts require the

RESUME command.

```
PIR1.0 = 0                'Clear Timer1 overflow interrupt
                          '  flag
resume                    'This is how we exit an
                          '  interrupt
```

Although this program isn't very long, it does demonstrate Timers and Interrupts quite well.

NEXT STEPS

You can easily change the IF-THEN test of "counter" to a larger or smaller value to make the LED flash faster or slower. Another option is to change the preset values for TMR1H and TMR1L and prescaler to see if you can get it to flash the LED faster or slower without changing the "counter" test value. If you put an oscilloscope probe on the LED, you can see how accurate your calculations are.

You can take this same setup and modify it to work with the Timer0, which overflows after 255 clock pulses and uses a few other special function registers. That will help you prove to yourself that you understand how this program works and at the same time develop a Timer0 sample program to use in the future.

For Atom users, this same example is in my book *Programming the Basic Atom Microcontroller*. Atom makes it a little easier than PICBasic Pro since it automatically sets and clears the proper register bits through the Basic commands for timers. You can still write directly to the registers in Atom if you want, you just don't have to. That's one reason the Atom is easier for the beginner than the PICBasic Pro compiler, but Atom doesn't allow assembly language interrupts and doesn't let you program any off-the-shelf PIC. PICBasic Pro is more of a professional compiler whereas the Atom is more of a hobbyist compiler. In either case, being able to access the Microchip PIC's internal features with simple Basic commands is really a treat. It also gradually introduces you to the inner workings of a PIC so moving to assembly language isn't such a big leap.

If you have any questions, comments, or project ideas, pass them on to me at chuck@elproducts.com. If you have developed anything using the information presented in my columns, send me a picture and a brief description of it. I've already received a few, and I'm really surprised how fast readers have moved from knowing very little about programming PICs to being able to do some very interesting projects. I hope to find time to post them on my website, so keep an eye out for that. **NV**

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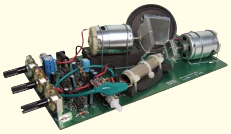

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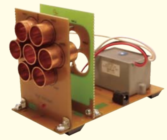

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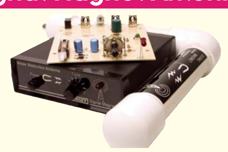

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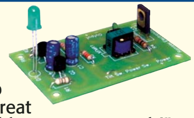

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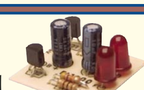

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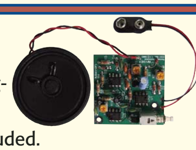

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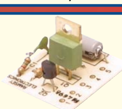
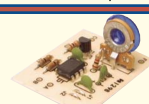


Produces the upward and downward wail of a police siren. Produces 5W output, and will drive any speaker! Runs on 6-12 VDC.

SM3 Electronic Siren Kit $7.95

Universal Timer



Build anything from a time delay to an audio oscillator using the versatile 555 timer chip! Comes with lots of application ideas. Runs on 5-15 VDC.

UT5 Universal Timer Kit $9.95

Voice Switch

Voice activated (VOX) provides a switched output when it hears a sound. Great for a hands free PTT switch, or to turn on a recorder or light! Runs on 6-12 VDC and drives a 100 mA load.

VS1 Voice Switch Kit $9.95

Tone Encoder/Decoder

Encodes OR decodes any tone 40 Hz to 5KHz! Add a small cap and it will go as low as 10 Hz! Tunable with a precision 20 turn pot. Runs on 5-12 VDC and will drive any load up to100 mA.

TD1 Encoder/Decoder Kit $9.95

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Super broadband preamp from 100 KHz to 1000 MHz! Gain is greater than 20dB while noise is less than 4dB! 50-75 ohm input. Runs on 12-15 VDC.

SA7 RF Preamp Kit $19.95

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TS1 Touch Switch Kit $9.95

What's New For 2006!
The Newest And Neatest Goodies
What Other Incredible New Products Are Coming Soon? *That Would Be Telling!*

Super Stereo Headphone Amplifier

New For 2006

- ✔ **The next generation of our famous SHA1!**
- ✔ **Separate volume, treble, bass, balance, and loudness controls!**
- ✔ **Stereo loop through!**
- ✔ **Audio clipping LED indicator!**

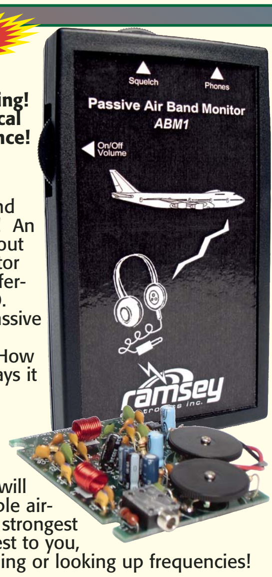
How could we take the highly popular SHA1 line level to headphone level amplifier and make it better? Consider it done with the SHA2!

Standard 3.5mm stereo headphone connectors are used throughout for today's "walkman" style headphones. Dual LM386's and LM1036's are used to provide nearly 1W output for the normal 4-40 ohm headphones or speakers. Customize your sound with separate volume, treble, bass, balance, and loudness controls. Dual outputs are provided for multiple listeners. Plus a loop through input is provided and properly isolated to prevent hum and ground loops. Runs on a standard 9V battery plus has an external 12-20VDC input. Available kit or assembled.

SHA2	**Super Stereo Headphone Amplifier Kit**	**$44.95**
SHA2WT	**SHA2 Amplifier Kit, Factory Assembled & Tested**	**$79.95**

Passive Air Band Aircraft Monitor

New For 2006



- ✔ **Monitors the entire aircraft band without tuning!**
- ✔ **Passive design, can be used on aircraft, no local oscillator, generates and creates no interference!**
- ✔ **Great for air shows**
- ✔ **Patented circuit and design!**

For decades we have been known for our novel and creative product designs. Well, check this one out! An aircraft receiver that receives all nearby traffic without any tuning. It gets better... there is no local oscillator so it doesn't produce, and can't produce, any interference associated with all other receivers with an LO. That means you can use it onboard aircraft as a passive device! And what will you hear? The closest and strongest traffic, mainly, the one you're sitting in! How unique is this? We have a patent on it, and that says it all!

This broadband radio monitors transmissions over the entire aircraft band of 118-136 MHz. The way it works is simple. Strongest man wins! The strongest signal within the pass band of the radio will be heard. And unlike the FM capture effect, multiple aircraft signals will be heard simultaneously with the strongest one the loudest! And that means the aircraft closest to you, and the towers closest to you! All without any tuning or looking up frequencies! So, where would this come in handy?

1. ***At an air show! Just imagine listening to all the traffic as it happens***
2. ***Onboard aircraft to listen to that aircraft and associated control towers***
3. ***Private pilots to monitor ATIS and other field traffic during preflight activities (saves Hobbs time!)***
4. ***Commercial pilots to monitor ATIS and other field traffic as needed at their convenience***
5. ***General aircraft monitoring enthusiasts***

Wait, you can't use a radio receiver onboard aircraft because they contain a local oscillator that could generate interfering signals.

We have you covered on that one. The ABM1 has no local oscillator, it doesn't, can't, and won't generate any RF whatsoever! That's why our patent abstract is titled "Aircraft band radio receiver which does not radiate interfering signals". It doesn't get any plainer than that! Available as a through-hole hobby kit or a factory assembled & tested SMT version.

SPECIFICATIONS

Frequency Range:	118 MHz to 136 MHz
Receiver Type:	Patented Passive Detector
IF Frequencies:	None!
Receiver Sensitivity:	Less than 2 uV for detectable audio
Audio Output:	700mW, 8-24 ohms
Headphone Jack:	3.5mm stereo phone
External Antenna:	Headphone cord coupled
Power Requirement:	9VDC battery
Dimensions:	2.25" x 2.8" PC Board 2.5" x 4.6" x .9" Case
Weight:	4 oz. with battery

ABM1	**Passive Air Band Monitor Kit**	**$89.95**
ABM1WT	**Passive Air Band Monitor, Factory Assembled & Tested**	**$159.95**

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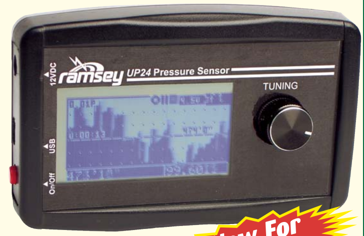
High Resolution Air Pressure/Elevation Sensor



New For 2006

- ✔ **Pressure resolution greater than 0.0001kPa!**
- ✔ **128 x 64 pixel graphical display!**
- ✔ **Shows realtime elevation & pressure changes!**
- ✔ **USB computer interface for easy data transfer!**
- ✔ **13,824 samples of FLASH storage available!**
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"The Most Advanced And Accurate Ramsey Kit To Date!"

We really did it this time! The UP24 is one of our most advanced kits to date, and an absolute MUST for anyone serious about the environment around us! But the applications only begin there.

The unique design allows unprecedented super high resolution measurements and display of absolute atmospheric air pressure. The UP24 senses ambient air pressure and critically calculates elevation with unheard of precision! Using a highly sensitive sensor and 24-bit A/D converter in a special noise-immune design, less than 1/3" of an inch of elevation resolution is achieved! YES, we said 1/3 of an inch! This high accuracy and resolution opens the door to a host of sophisticated environmental air pressure monitoring applications.

Unlike your normal run-of-the-mill barometer, air pressure is sensed in Pa's or kPa's. What are those you may ask? Pascals or KiloPascals. However, don't be afraid, for your convenience, and to fit any application you may have, it is also displayed in millibars, bars, PSI, atmospheres, millimeters of mercury, inches of mercury, and feet of water! Take your pick! The range of the UP24 is 15kPa to 155kPa.

We've talked about air pressure, now let's talk about elevation! The incredibly precise 24 bit A/D converter in the UP24 looks at the air pressure and converts it to elevation above sea level. In both graph and text, the elevation is displayed to a resolution of 1/3"! Yes, I said 1/3 of an inch! The applications for the super accurate elevation meter are endless. From watching and recording elevations during hiking trips to measuring and recording the wave heights on boats! Let your imagination take over from there!

What if you're in the field and you want to save data captured in your UP24? The built-in FLASH storage provides 13,824 samples of storage. Then you can transfer your data to your PC with a standard USB interface.

While the UP24 is small enough to be kept in your coat pocket it boasts a large 2.78" x 1.53" 128x64 pixel LCD display screen making viewing easy. Display modes include both realtime pressure and elevation graphs as well as pressure and elevation statistics. There are 12 user selectable sample rates from 1/10th of a second all the way up to every 15 minutes.

Needless to say, you cannot put all the specs and screen shots in the limited space of this ad! Visit our website at www.ramseykits.com for full specs and information.

If you're looking for the finest air pressure and elevation sensor, check out the UP24, truly a marvel in the industry! Available in a ready-to-build kit or a factory assembled and tested version. Check our website at www.ramseykits.com for more information!

UP24	**High Resolution Air Pressure/Elevation Sensor Kit**	**$239.95**
UP24WT	**Factory Assembled and Tested UP24**	**$299.95**
AC125	**110VAC Power Adapter/Charger**	**$9.95**

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Q&A

WHAT'S UP:

MOSFETs! Everything you wanted to know and aren't you sorry you asked! Practical apps for them and lots of theory.

- ✔ IGBT photoflash circuit.
- ✔ Switching on the high-side.
- ✔ TV to PC.
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■ WITH TJ BYERS

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist.

Feel free to participate with your questions, comments, or suggestions.

You can reach me at: **TJBYERS@aol.com**

MOSFET BASICS

Q Thanks a lot for the "Heater Fan Controller" circuit in the December '05 issue. Looks interesting! I have a few different types of DC motors to try this circuit on. While looking over the controller, a question came to mind. I don't know that much about MOSFETs or FETs in general. What makes them tick?

— Bob J.

A Ray Marston did a very good job of describing FETs and MOSFETs in his May, June, July 2000 series in *Nuts & Volts*. But it focuses mostly on low power devices, which behave differently than high-power FETs. Let me try to explain.

The original transistor — invented in 1947 by a team of John Bardeen, William Shockley, and Walter Brattain at Bell Telephone Labs — was a bipolar device that amplified a small input current into a higher output current, as opposed to amplifying a small input voltage into a higher output voltage. Let me tell you, for us vacuum tube (valve) guys, it was a quantum leap in thinking about circuit design. I can't count the number of CK722 transistors I fried by trying to apply voltage rules to a current device.

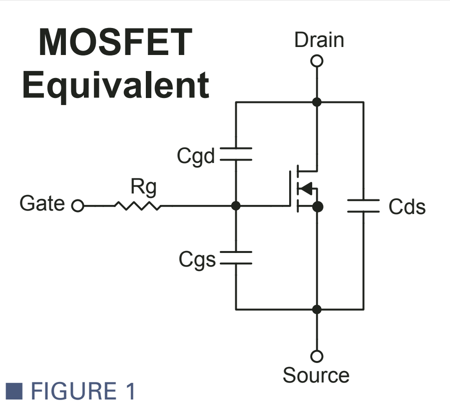
Somewhere between 1960 and 1963 the epitaxial deposition transistor evolved into the junction field-effect transistor — JFET. Like the vacuum tube, the JFET is a voltage controlled device where a negative voltage is needed to "pinch" off the flow of electrons from source (cathode) to drain (plate). Cool for us tube guys, but hardly a tube substitute.

At about the same time, the metal-oxide semiconductor field-effect transistor — MOSFET — came into being and allowed us to combine tube technology with transistor. That is, an increase in voltage prompts an increase in current flow. Most "FETs" today are of this enhanced-mode type.

While MOSFETs can be operated in the linear region, most are used as switches — where they are either ON (conducting) or OFF (not conducting). In this mode, there are two important parameters to consider: switching time and saturation voltage. The first is the time it takes for the transistor to go from OFF to ON, and vice versa. The more time the transistor spends between the two states, the more power it dissipates. The switching times are determined by the capacitance of the gate junction. Because the gate is insulated from the rest of the semiconductor bulk, a capacitor is formed between the gate and source, and the gate to drain, as shown in Figure 1. These capacitors have to be charged before the gate voltage reaches a high enough potential to turn the MOSFET on.

Although the gate-to-source capacitance is important, the gate-to-drain capacitance is actually more significant. And more difficult to deal with because it's a non-linear capacitance affected as a function of voltage. This capacitance is similar to that found in vacuum tube amplifiers — a phenomenon known as the "Miller" effect, a function by which feedback between the input and output of an electronic device is provided by the interelectrode capacitance. Though smaller than gate-to-source capacitance, the gate-to-drain capacitance goes through a voltage excursion that is often more than 20 times that of the gate-to-source capacity. Therefore, the gate-to-drain or Miller capacitance typically requires more actual charge than the input capacitance.

The MOSFET switching time is



■ FIGURE 1

divided into four sections as shown in Figure 2.

1) During this period, the gate voltage (V_{GS}) is charging the input capacitor — which is dominated by the gate-to-drain capacitance (V_{gd}).

2) At V_{th}, drain current begins to flow. During this time, the drain voltage (V_{DS}) is typically constant at the source voltage (V_{CC}).

3) This is the stage where the Miller plateau (V_{plt}) is reached, at which time the drain voltage — ON resistance — begins to linearly decrease until the end of the third period. This occurs when V_{DS} reaches 10% of its OFF value. It's during this period that the MOSFET dissipates most power and heat.

4) In region 4, the MOSFET is fully saturated, and the ON resistance is at its minimum. V_{GS} continues to increase to its full driving value — typically 15 V.

By increasing the gate voltage, the Miller capacitor can be forced to charge faster, and that decreases the switching time. The discharge time of the MOSFET is a mirror image of this profile, with the Miller plateau discharge time governed by the resistance of R_G — the gate input resistor.

Want more MOSFET stuff? Check out "IGBT Basics" below.

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A What is the best digital format to send schematic diagrams to you?

— Tyler

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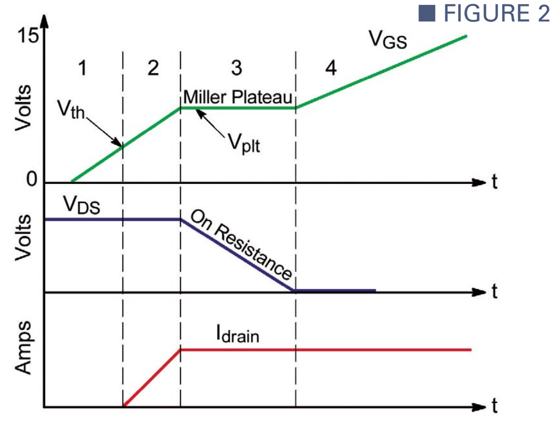
■ FIGURE 2



MOSFET Turn ON Characteristics

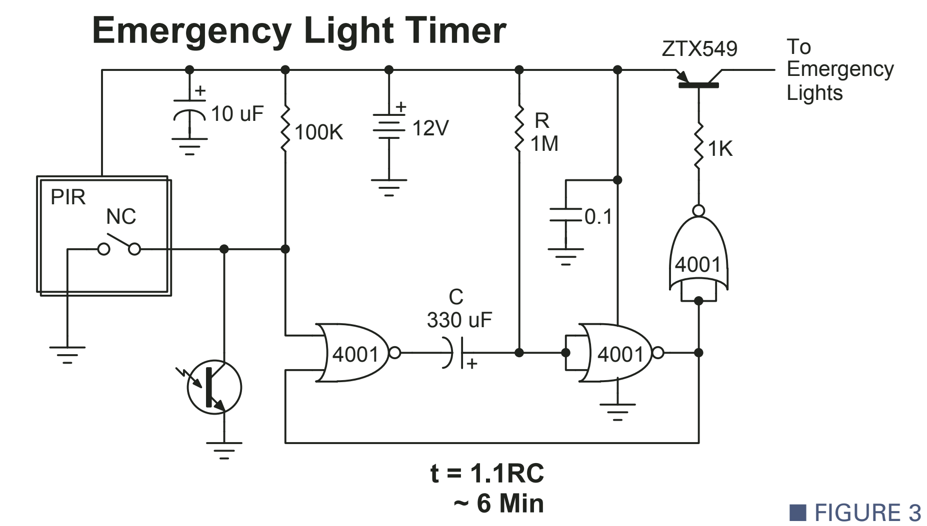
ESCAPE FROM L.A.

Q Where I live, power outages are frequent. So when the lights go out, I have an emergency backup system that provides lighting from a 12-V gel-cell. However, the blackouts often last for several hours, sometimes days — but my backup battery is only good for a few hours. And if the power goes off in the middle of the day, the battery is often dead by the time the sun sets.

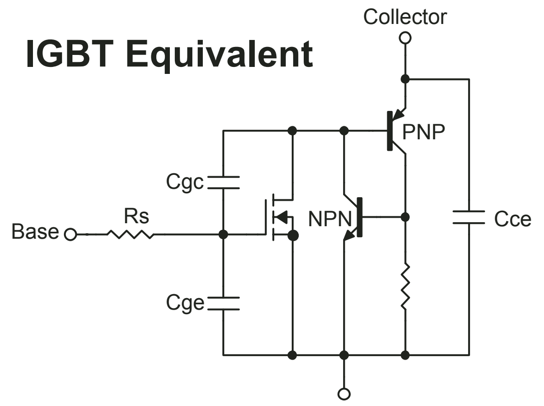
I'm looking for a timer that would turn on the emergency lamp for about five minutes, then go off to conserve power. I want to connect a motion detector to the lamp so that it turns on only when motion is detected, and then only for the time specified. The circuit should have a low parts count (I want to assemble more than one) and have nearly zero current drain in the off state. A circuit without relays — one that can be modified to run 1-30 seconds, 1-30 minutes, etc., by substituting different RC values — would be ideal. I have constructed everything, including the LED light heads and constant-current regulators, except for the timer. Have any ideas?

— Dusan
Los Angeles, CA

A The best way to keep the quiescent current low is to use CMOS logic for the timer, like the 4001 NOR gate. When configured as a one-shot multivibrator (Figure 3), the 4001 draws less than 1 µA in the OFF state — in fact,



■ FIGURE 3



■ FIGURE 4

Parameter	BJT	MOSFET	IGBT
Breakdown voltage	> 1,000V	< 1,000V	> 1,000V
Input impedance	Low	High	High
Drive method	Current	Voltage	Voltage
Drive current (leakage)	1 A	100 nA	100 nA
Saturation voltage	Low	High	Low
R_{on} ohms (typical)	0.13	0.27	0.084
Operating frequency	100 kHz	1 MHz	150 kHz
t_{on} time	4.5 µs	39 ns	48 ns
t_{off} time	9.0 µs	39 ns	340 ns
Total time	11.5 µs	78 ns	388 ns

■ TABLE 1. Power Device Comparison.

the 100 kΩ pull-up resistor draws 100 times more current at 0.1 mA. When your motion detector (PIR) goes off, the NC (normally-closed) switch goes open and triggers the timer. This causes capacitor C to start charging through resistor R — and turns on the PNP transistor. The ZTX549 is unique in that it has very low voltage drop across it — somewhere in the order of 100 mV at 100 mA — further saving battery power. If you don't have a ZTX549 (available from Digi-Key) lying around, a 2N4402 or equivalent will do.

After a time of t = 1.1(RC), the pass transistor turns OFF and stays OFF until the PIR cycles by closing its internal switch (no motion) and then opening it again (motion). To prevent triggering of the emergency lamp when the sun is up, a phototransistor clamps the timer's input low. After dark, the phototransistor turns off and allows the PIR to control timer operation. Don't be tempted to eliminate the 10 µF and 0.1 µF bypass caps. They are critical to the stability of the circuit; place the 0.1 µF as close to pin 14 of the 4001 as possible.

IGBT BASICS

Q Thirty years ago, while attending the University of Illinois, I ran a photo service taking fraternity/sorority dance pictures and portraits to make spending money. After graduating, I gave up photography but held on to my old Grafles Stroboflash equipment. Now with more time on my hands, I decided to take up photography again. My wife bought me a new Nikon D70 for Christmas and I was off … 'til I discovered that the 225 V batteries for each strobe unit (I have six) cost $200 each! Being the "evil genius" that I fancy myself, I decided to build my own strobes running off AC mains using the old flashtubes.

After researching the new technologies, I decided to go with IGBT transistors instead of SCRs because they allow me the most control, letting me operate them from a PIC or Stamp microcontroller. Here is my problem: There's not a whole lot of info on IGBTs. And what is out there is Greek to a person with a degree in ME not EE. Can you explain them in terms I can understand?

— Albert J Sanowskis
Reddick, FL

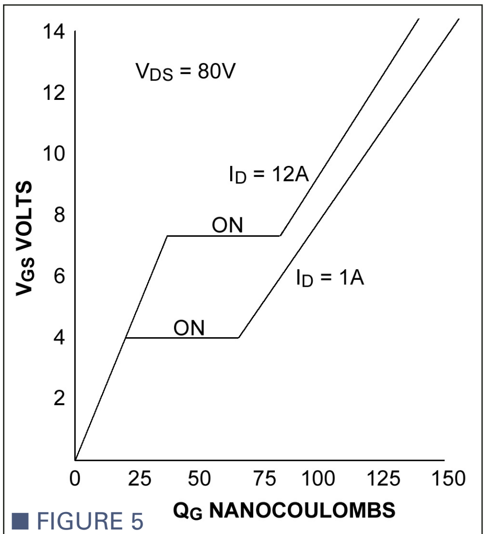
A The IGBT (insulated-gate bipolar transistor) is basically the marriage between a MOSFET (metal-oxide field-effect transistor) and a bipolar transistor. It has the output switching and conduction characteristics of a bipolar transistor, but is voltage-controlled like a MOSFET. Generally, this means it combines the high-current-handling capability of a bipolar part with the ease of control of a MOSFET.

The structure of an IGBT die is similar to an N-channel MOSFET, with one added junction. This added junction effectively becomes the collector of the PNP bipolar transistor, which is driven by the N-channel MOSFET. Besides the PNP transistor, there is an NPN transistor that forms a Darlington pair (Figure 4), thereby giving the IGBT its bipolar output characteristics.

This variation between MOSFET and IGBT is enough to produce some clear distinctions as to which device serves which applications better. Clearly, the IGBT is the choice for breakdown voltages above 1,000 V, while the MOSFET is better for breakdown voltages below 250 V. When the breakdown voltage is from 250-1,000 V, choosing between them is a very application-specific task in which cost, size, and speed must be taken into account.

IGBTs have been the preferred device under the conditions of low duty cycle, low frequency (less than 20 kHz), and high output power in excess of 5 kW. Typical IGBT applications include motor control, UPS power supplies, high-current welding, and low-power lighting with operation frequencies below 100 kHz.

MOSFETs are preferred in appli-



■ FIGURE 5

cations where high-frequency operation above 200 kHz is required, with wide line or load variations, long duty cycles, low-voltage applications (less than 250 V), and low output power (under 500 W). Typical MOSFET applications include switching power supplies and battery charging. Of course, nothing is as easy as it seems. Tradeoffs and overlaps occur. See Table 1 for a direct comparison of bipolar, MOSFET, and IGBT.

The front end of the IGBT is essentially identical to that of the MOSFET, and should be treated accordingly. That is, you have to respect the Miller charge effect and the plateau that the transistor must go through to become fully saturated (see "MOSFET Basics" above). Figure 5 shows the gate characteristics for a typical IGBT device in the switch-on mode. Notice that the charge is measured in coulombs (Q_G). Doing the math — $C = Q_G / E$ — we calculate that C_g is 0.01 µF.

Enter Rs — the gate series resistor. This resistor determines the time it takes for the transistor to go from full OFF to full ON by restricting the flow of current to the input capacitance using the formula $t = 5(RC)$. The smaller Rs is, the faster the transistor will switch on. It also reduces external noise that can falsely trigger the transistor. On the other hand, large inrush currents can stress the gate junction by momentarily causing the gate voltage to exceed V_{GE} thresholds. But as Rs increases, so does the turn-off time. This is great if you want soft turn-off, but not good for flyback applications. As you can see, a proper gate driver and Rs value is critical to the success of your design. Most datasheets show the value of Rs they used to generate the parameters and test results listed. This is a good place to start.

Back to your specific application of building a flashtube controller, I suggest the circuit in Figure 6. For the driver, I chose the IR4427 (Figure 7) because it can sink and source up to 1.5 A — and is ideally suited for driving MOSFET and IGBT transistors. Taking the value of Rg from the IRG4BC40F datasheet, and using conventional IGBT input design, I came up with the 10-Ω series and 20-kΩ parallel resistor input combination. When a positive pulse is applied to the input of the IR4427, it triggers the IGBT — which, in turn, discharges the 0.22 µF cap through the trigger coil and fires the flashtube. Notice that the IR4427 has two drivers in its package, which means it can drive two flashtubes or be paralleled for more drive current. Providing the 320-V charging voltage and programming the PIC is up to you.

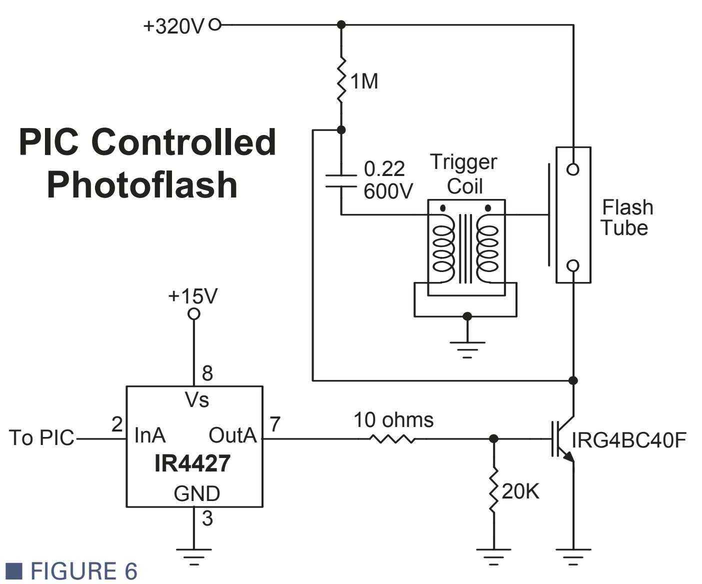


FIGURE 6

Can't get enough MOSFET stuff? Continue this thread with "You Take The High Road ..."

PC TV BASICS

Q I have been using an ATI TV Wonder (external USB 2.0 version) for transferring home video onto my laptop for editing with great success. I'm now going on a road trip this summer and would like to take along the ATI TV Wonder for watching TV on my journey. While it picks up a lot of channels, they're all fuzzy. I have tried every antenna in our house, but the reception is still horrible. Is there anything — tips, circuits, etc. — to improve this?

— Ian Rab

A Like all PC TV video cards, the input expects an input voltage of about one millivolt — like that from cable TV — not the microvolts the TV antenna outputs. The solution is to amplify the signal from the antenna using a TV antenna preamp, like those sold by Winegard, Blonder, RadioShack, and others. Simply place the preamp between the antenna and ATI TV Wonder (Figure 8) — or whatever PC TV adapter you have — and that's it. The preamp requires a

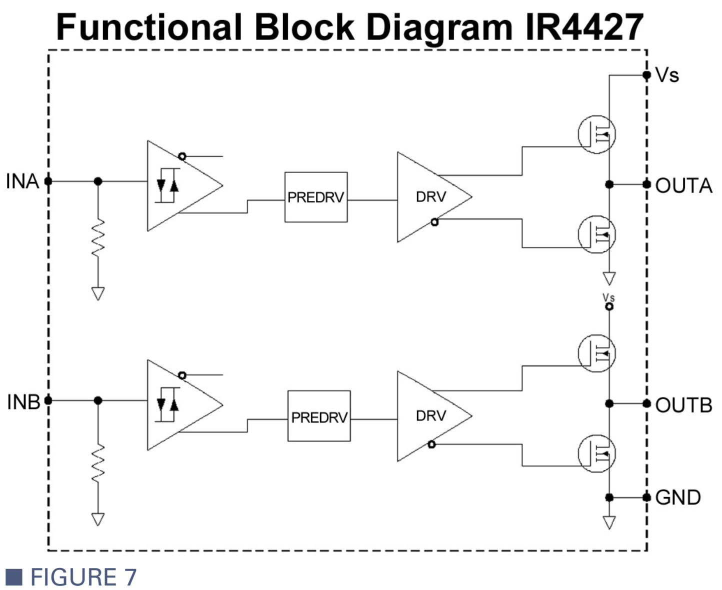
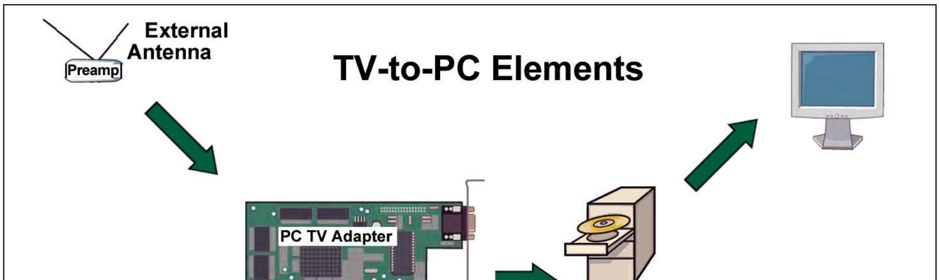


FIGURE 7



■ FIGURE 8

separate wall-wart power supply, so expect to be near an outlet when watching TV. If you plan on spending a lot of time on the road, consider the Audiovox AN300 Amplified TV Antenna, which works off the cigar lighter and is available from most RV suppliers for under $40.

YOU TAKE THE HIGH ROAD ...

Q I've been a relay man all my life and I'm used to being able to switch a load in and out of a circuit in any combination I wish from any source I wish. Today, most relays have been replaced by semiconductor switches, like MOSFETs. But most designs require you connect the load to the Vcc and the MOSFET turns on the load by grounding it. Can the bottom side of the load be placed at ground instead, with the MOSFET switching the Vcc?

— James T. Kirk

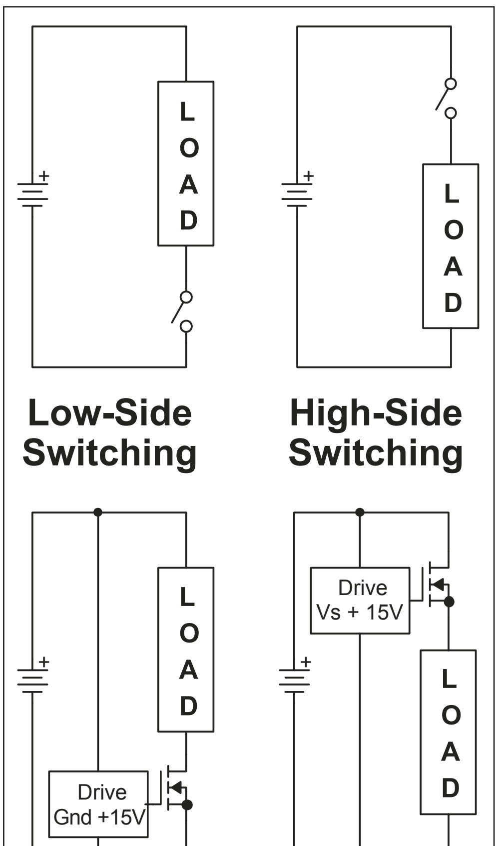
A Cute handle; is it your real name? What you are asking for is called high-side switching. You are correct that most circuits use low-side switching where the load is either grounded or floating. In many applications this is not desirable for many reasons: shock hazard, sensitivity to static discharge, physically not possible (especially in auto applications), and more. Figure 9 shows the difference between low- and high-side switching.

In this figure, both the mechanical and semiconductor versions of low-side and high-side switching are shown. Flipping the mechanical switches is a no brainer, but not computer friendly. For that you need a relay — or a semiconductor switch, like the enhanced mode MOSFET or IGBT. Switching the low side is very easy, and the reason it's the most prevalent. For details, refer to the other sections "MOSFET Basics" and "IGBT Basics."

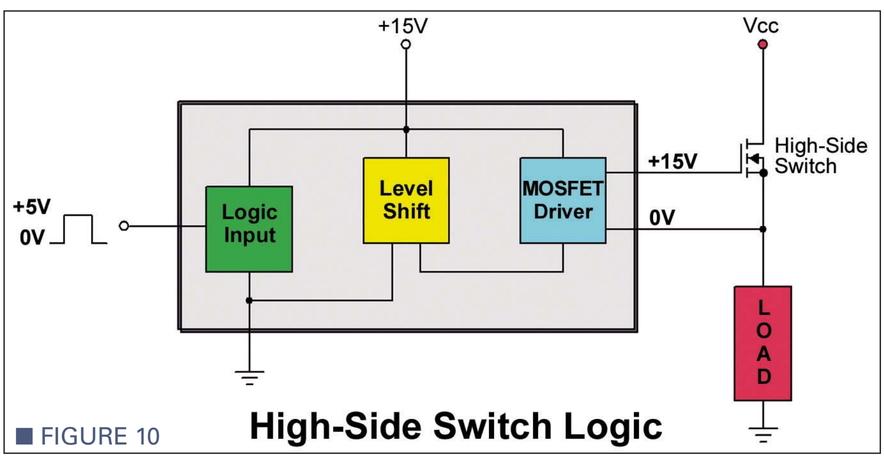
Switching on the high-side, on the other hand, requires the driver to ride atop ground, making reference to the MOSFET's source terminal instead. There are several schemes used to do this, but the typical solution is to use a high-voltage driver like that shown in Figure 10. A typical IC for this application is the IR2117. Here's how it works. The MOSFET doesn't care where the 15 V it needs to saturate the switch comes from. For all it cares, you can slap a 15-V battery across the gate-to-source connection and it will be a happy camper.

The circuit itself is less forgiving. That is, ideally the top of the load would be at Vcc — which means that the gate voltage has to be Vcc *plus* +15 V before it will switch on. This is where the high-side driver voodoo comes into play. It separates the Vcc to the load from the driver circuit. The circuitry needed to do this is rather complex and must be able to withstand the voltage differential between Vcc and ground. Which is why we have high-voltage ICs like the IR2117.

If you're working with low-power high-side switching — something on the order of three amperes or less — then the circuit in Figure 11 may suit your needs. Here the isolation between the TTL logic and Vcc high voltage is via a 4N25 optoisolator.



■ FIGURE 9



■ FIGURE 10

When the 4N25 LED goes on, its internal transistor turns on and provides bias current to the PNP pass transistor and turns it on.

DVD BLUES

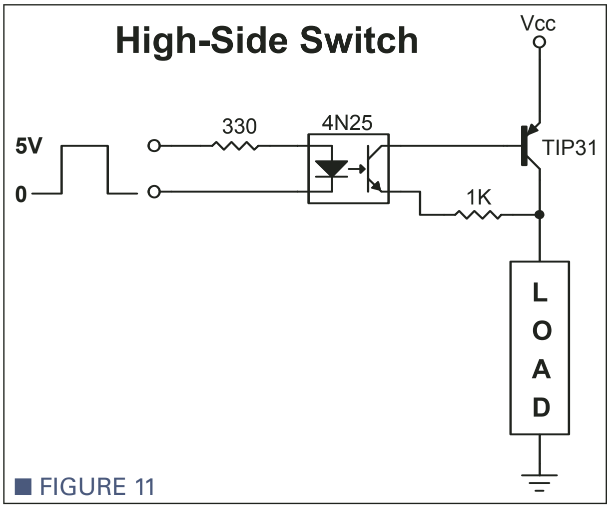
Q I was interested in getting a CD recorder (not hooked to my PC) to record the audio off some of my concert video tapes so that I could hear them on my PC. Unfortunately, I can only find DVD recorders, and I've heard you can't make an audio CD on them. Can you clarify these different recording methods, and maybe provide a solution?

— Paul

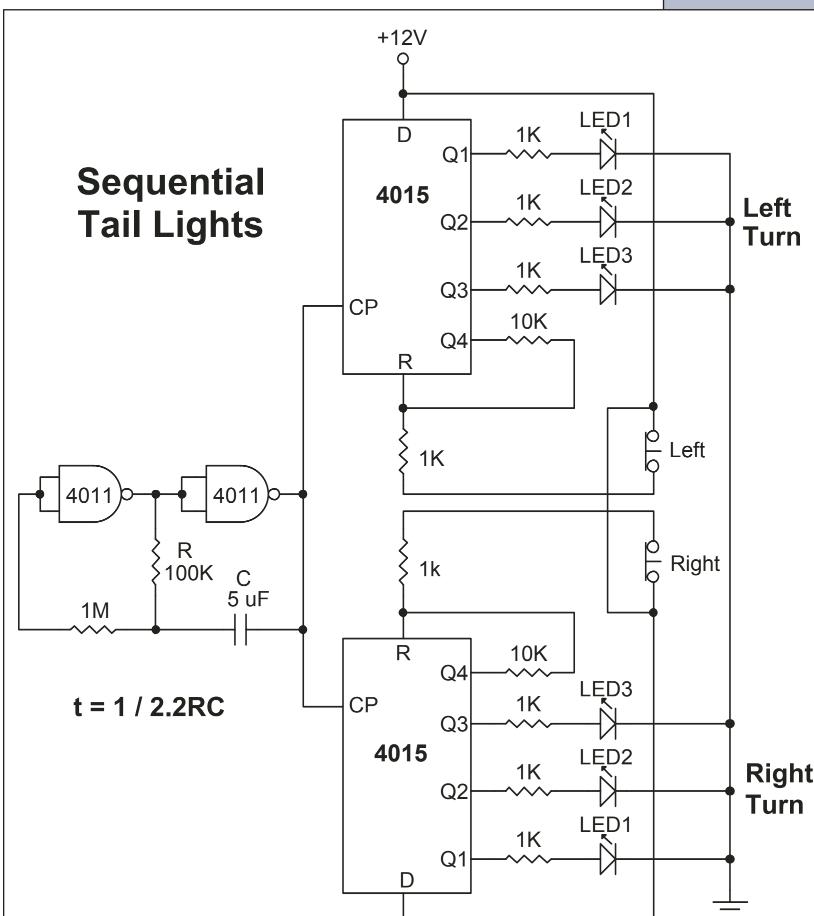
A The difference is in the format, of which there are many. The first CDs were audio Compact Disk, which can store 650 MB of music — about 74 minutes' worth. The format of the audio disc, known as the "Red Book," was laid out by Sony and Philips in 1981. In broad terms, the format is a two-channel stereo 16-bit PCM (pulse-code modulation) encoding at a 44.1 kHz sampling rate.

DVD is an optical disc storage media format that can be used for all sorts of data storage, including video and sound. Although DVDs physically resemble Compact Discs, they are encoded in a different format and at a much higher density. A typical DVD can store 4.7 GB, about two hours of movie-quality video. Commercial DVD movies are encoded using a combination of MPEG-2 compressed video and audio of varying formats (often multi-channel formats). Typical data rates for DVD movies range from 3-10 Mb/s, with a video resolution of 720 × 480 (NTSC) and 720 × 576 (PAL). A high number of audio tracks and/or lots of extra material on the disc will often result in a lower bit rate (and lesser image quality) for the main feature. There are two DVD audio formats: DVD-Audio and SADC, neither of which is supported by today's DVD players (well, almost none). For more details, check out **www.webopedia.com/DidYouKnow/Hardware_Software/2003/DVDFormatsExplained.asp**

A DVD recorder won't record unless there is a video signal present. If you wish, you can record



■ FIGURE 11



■ FIGURE 12

MAILBAG

Dear TJ,

In the March issue — page 23, Figure 5 ("Sequential Tail Lights") — I think the correct formula is f = 1 / 2.2(RC).

— Craig Kendrick Sellen
Carbondale, PA

Response: *Actually there were two errors in that drawing. The corrected version is shown in Figure 12. For those readers who didn't understand that this circuit was for a model car and not the real thing, find a grown-up version in the April 2006 issue.*

Dear TJ,

One possible solution for Alex Curiel's search for an IR repeater (Feb. 2006, page 13) is Ramsey Electronics' (**www.ramseykits.com**) IR Repeater kit #RR1C. I assembled the kit about three weeks ago and am very pleased with the results. I use the repeater to activate my DVD recorder which I had placed in a cabinet. The DVD's IR receiver was hidden behind the wood frame of a glass door and could not see its remote transmitter. I placed the RR1C's remote IR transmitter LED next to the DVD recorder and now everything works great.

— Rich Van Workum

a low-grade video alongside your audio — record it in the eight-hour mode — then just turn the TV off when you play it back. But, that kinda defeats the purpose of playing your tunes on the PC and working on the monitor at the same time. While you can't buy audio CD recorders from Best Buy, you can find them on eBay for under $100. I prefer Pioneer recorders; I've had good luck with them.

SMART SWITCHERS

Q Your excellent answers in the Dec. 2005 and Feb. 2006 issues made me aware of International Rectifier's Intelligent Power Switches (IPS) series of power FETs for the first time. Are those special OEM parts for automotive use and are there more types than the IPS021 and IPS031 in this series? Please suggest a supplier where I can obtain some because my local distributors couldn't cross-reference them in their catalogs.

— Ted Ross
Santa Barbara, CA

A A good selection of IPS switchers are available from Digi-Key (800-344-4539; **www.digikey.com**). They come in both low-side and high-side versions (see above) and have built-in MOSFET drivers that switch at 5-V logic. All are designed to work in the harsh environment of the automobile where voltage surges can get up to 50 V. Most switch in the 5-12 A range — although select devices can switch up to 75 A — and the switching speed is under 20 kHz, which is pretty much in keeping with the discussions above. I don't have space for a full chart of these devices, so look it up at: **www.irf.com/productinfo/ips** NV

COOL WEBSITES

If you don't mind getting on every mailing list in the world (well, almost every), participate in this promotion and receive a free Polaris 60mm AZ-D Telescope — a $130 value:

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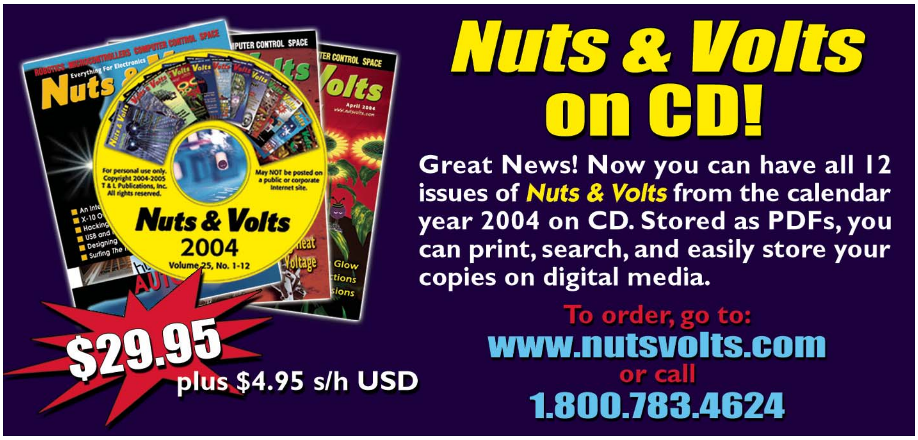
Hubble's largest portrait ever offers a high-definition view of the M101 spiral galaxy — nicknamed the Pinwheel Galaxy. A composite image measuring 16,000 by 12,000 pixels is downloadable as a JPG file, PC wallpaper, and PDF printable:

http://hubblesite.org/newscenter/newsdesk/archive/releases/2006/10/image/a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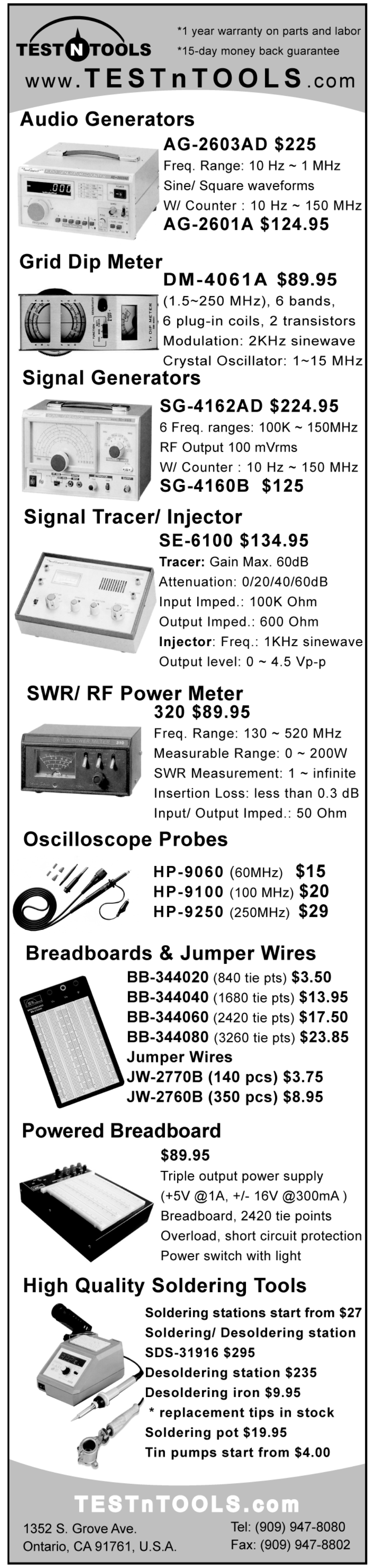
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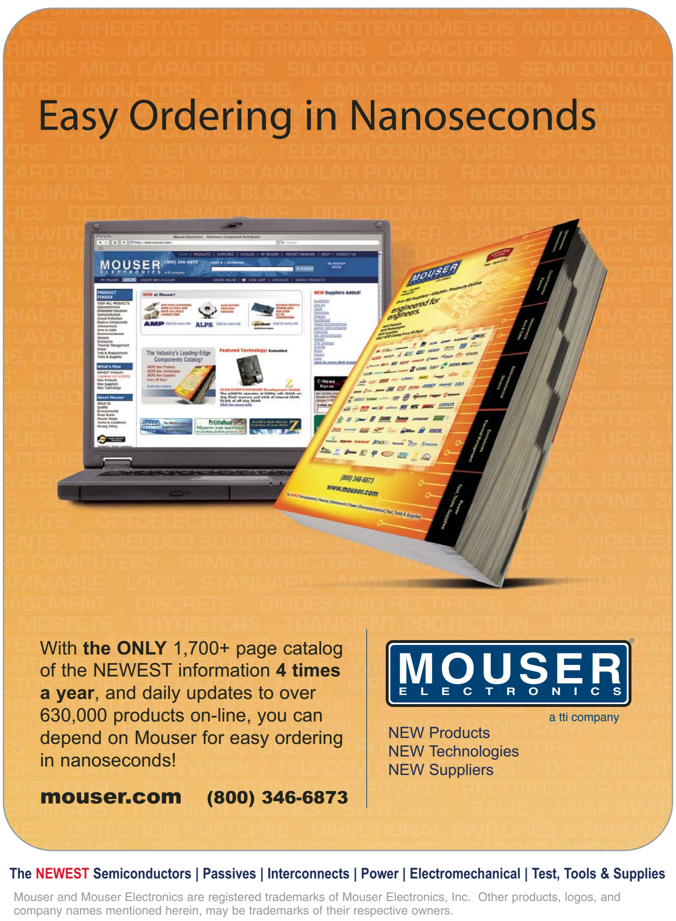
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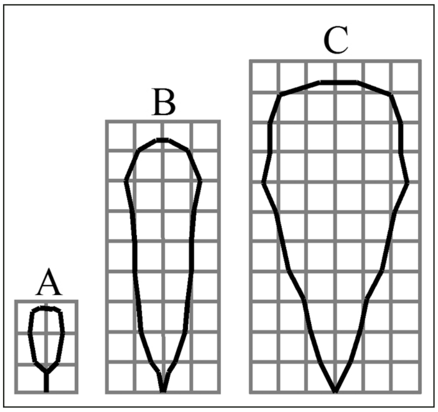

The MaxSonar-EZ1 from Maxbotix is a high-performance ultrasonic range finder. The sensor is a completely new design, yielding many improvements over traditional ultrasonic range finders.

The MaxSonar-EZ1 detects objects from 0 to 255 inches (0 to 6.45 m) with no dead zone and provides very stable range readings from six to 255 inches in one-inch increments. Objects closer than the six-inch range show as six inches. The sensor utilizes a single 42 kHz ultrasonic transducer coupled with a continuously-variable high gain amplifier to yield a controlled narrow ultrasonic beam. Filling a volume of less than one cubic inch, the MaxSonar-EZ1 is half the size of competing sensors, while the 2 mA nominal current draw is the lowest of any range sensor.

For ease-of-use, the MaxSonar-EZ1 has holes for mounting, and provides the range directly, using three user interfaces. The pulse width output provides 147 uS per inch. The analog voltage output provides 10 mV per inch output and always holds the latest range reading. In addition, the 9,600-baud serial output sends information after each range event.

Superior beam quality is demonstrated. Large objects such as a wall are detected to 254 inches and detection patterns for selected objects are shown in the figure. The background is a 12-inch grid. Small objects such as a 0.25-inch diameter dowel (A) are detected in a very narrow zone to almost three feet. Larger objects such as a one-inch diameter rod (B) have a long narrow detection pattern. Fairly large objects such as a 3.25-inch diameter rod (C) have a long controlled detection pattern.

The MaxSonar-EZ1 is a low-cost sonar sensor priced at $29.95 (MSRP), with significantly lower prices to distributors, OEM users, and educators.

For more information, contact:
Maxbotix
Email: **bob@maxbotix.com**
Web: **www.maxbotix.com**

HEAT SHRINK
TUBING DISPENSER HOLDS FIVE POPULAR SIZES

A new bench-top or wall-mount, see-through dispenser that holds five popular sizes of PVC heat shrink tubing for design, assembly, service, and repair applications is being introduced by Insultab of Woburn, MA.

The Insultab PULL-PAK® Dispenser holds five mini-spools of highly flame retardant, low shrink temperature 1/16", 1/8", 3/16", 1/4", and 3/8" PVC heat shrink tubing; in black or bright colors. The dispener lets users easily see what they need, pull out the exact length, and cut it. Most importantly, the tubing stays in place and won't unravel or pull back.

Featuring a clear canister and sturdy stand, the Insultab PULL-PAK® Dispenser holds 100' of the 1/16" dia. tubing and 25' each of the 1/8", 3/16", 1/4", and 3/8". The PVC heat shrink tubing has a 2:1 shrink ratio, meets UL-, CSA-, and MIL-specifications, and is RoHS compliant. The dispenser is supplied with black tubing, but a wide variety of bright colors are offered.

The Insultab PULL-PAK® Dispenser is priced from $129.95 (suggested retail). Literature is available upon request.

For more information, contact:
Insultab
45 Industrial Pkwy.
Woburn, MA 01801
Tel: **781-935-0800**
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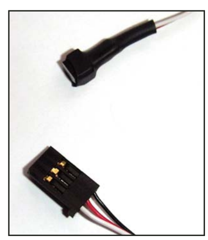
NEW OPTICAL RPM AND MICRO
TEMP SENSORS

Eagle Tree Systems announces the availability of Optical RPM and Micro Temperature sensors, based on customer feedback.



The Optical RPM Sensor measures RPM of your vehicle without the need for installing magnets, making it ideal for quick or temporary installations. There are

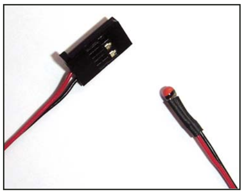
two types of Optical sensors available:

- Three Wire Optical RPM sensor for Flight, Boat, and Car Seagull and Data Recorder Products.

- Four Wire Optical RPM sensor for MicroPower e-Logger Products.

All MicroPower units will support the Optical RPM Sensor without a hardware upgrade (make sure you order the four wire version, found on the MicroPower page). However, Recorder firmware version 4.XX is required for Flight, Car, or Boat Seagull/Recorder owners.

The Micro Temperature Sensor is perfect for measuring temperatures of battery packs or ESCs. Its small size lets it slip easily into hard-to-reach places, such as between cells of a LiPo pack, under heat shrink, etc. The Micro Temp Sensor is fully compatible with all of Eagle Tree's Seagull, Recorder and MicroPower products.



For more information, contact:
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RAPID-Pi

MAKES EDITING MATHEMATICAL EQUATIONS FASTER

Trident Software Pty Ltd. now offers Rapid-Pi, an equation editing add-on for Microsoft Word. Rapid-Pi provides a new, faster way of creating and editing mathematical formulas and equations in documents.

Microsoft Equation Editor (often referred to simply as "the Equation Editor") is an equation editing program that comes with Microsoft Word. Equation Editor supports a variety of mathematical symbols and is very easy to use. Unfortunately, editing math with the Equation Editor can become a highly time-consuming process for regular users.

Equation Editor requires users to go through toolbars and menus to insert symbols one by one, like beads on a string. Math teachers, students, and others who frequently create documents containing mathematical expressions often find that writing math using the Equation Editor can be unacceptably slow.

Rapid-Pi provides a faster way to input equations and formulas. Mathematical expressions can be entered as easy-to-understand text. For example, the user can type "(y+2)/x^2" to create a fraction containing "y + 2" in the numerator and x-squared in the denominator.

Rapid-Pi's text-based input is similar to that used by graphing calculators and so will be instantly familiar to most math students and teachers.

While Rapid-Pi's input method does require some initial learning, this investment is soon paid off with ongoing time savings.

Few people have time to read a User Manual. That's why Rapid-Pi comes with a short "Getting Started Guide" that covers the most common expressions and symbols and allows the user to start editing math with Rapid-Pi in as little as five minutes.

Rapid-Pi also has a symbols toolbar containing all symbols and expressions supported by Rapid-Pi. If a user needs to enter a particular symbol for the first time, the user can just click on the corresponding toolbar button and Rapid-Pi will insert the correct textual keyword for the symbol (for example, ".a" for lower-case alpha, ".int" for integral).

After using Rapid-Pi for a few hours, most users will find that they remember the keywords for commonly-used symbols and rarely need to rely on the toolbar. However, the toolbar remains available as a fallback option for occasions where the user forgets a keyword or needs to enter a symbol he or she has never used before.

Rapid-Pi also includes a comprehensive User Guide and a Symbols Reference, providing detailed information about all features and symbols supported by Raid-Pi.

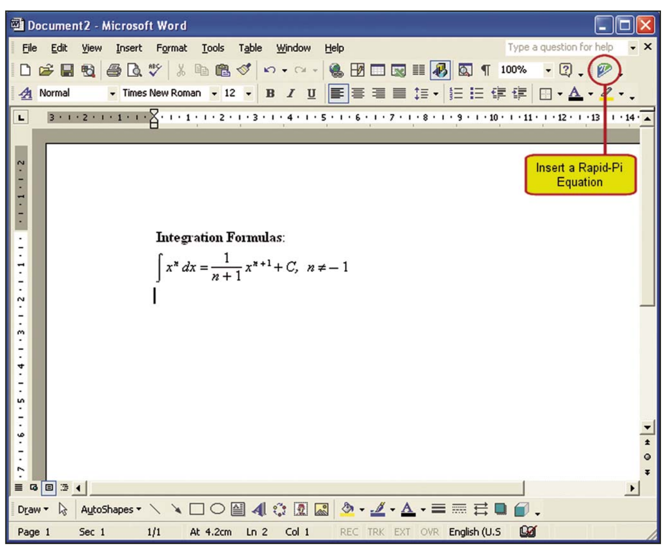
Rapid-Pi supports a wide range of mathematical symbols and expressions, including all symbols supported by the Equation Editor.

Rapid-Pi integrates with Microsoft Word (version 2000 or later), allowing users to insert a Rapid-Pi object into a Word document with one click.

Rapid-Pi also has an AutoSuggest facility which allows the user to quickly correct misspelled keywords. When a keyword is misspelled, Rapid-Pi underlines it with a red squiggly line. Right-clicking on the keyword displays a list of suggestions.

Rapid-Pi requires Microsoft Windows 2000 or Windows XP and integrates with Microsoft Word 2000 and later. Rapid-Pi can also be used with other word processing and editing applications.

Rapid-Pi is available in a number of license types to suit the needs and the budget of different users. All licenses include free technical support via email and 12 months of upgrades. Prices start at $20 (US) for a



Student License, while the Home/Small Office license is priced at $50 (US). A 30% Academic Discount is also available. More detailed information is provided at www.rapid-pi.com/pricing.aspx

A fully-functional 60-day evaluation version of Rapid-Pi can be downloaded from www.rapid-pi.com/download.aspx

For more information, contact:
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ALPHA EF-6100
LOW-SOLIDS WAVE SOLDER FLUX

Cookson Electronics Assembly Materials (CEAM) announces the global launch of ALPHA EF-6100 low-solids wave solder flux, the latest addition to its steadily expanding line of EF-Series environmentally-friendly fluxes designed for new lead-free processes, as well as tin-lead processes. This no-clean, alcohol-based flux provides best-in-class reliability, passing all international reliability standards including IPC, Bellcore, and JIS.

"ALPHA EF-6100 offers low residue for excellent board cosmetics and pin-testability for lead-free and tin-lead applications," said Steve Brown, Global Product Manager at CEAM. "Additionally, EF-6100 meets all IPC, Bellcore, and JIS electromigration and surface insulation resistance standards — confirming its exceptional electrical reliability."

Fully lead-free capable ORL0, ALPHA EF-6100 leaves minimal colorless, non-tacky, clear flux residue that spreads uniformly over the surface of printed circuit boards. It provides excellent resistance to connector bridging across a broad range of process conditions. It is compatible with all common pad finish types and improves yield by reducing defects, minimizing rework, and increasing throughput.

For more information, contact:
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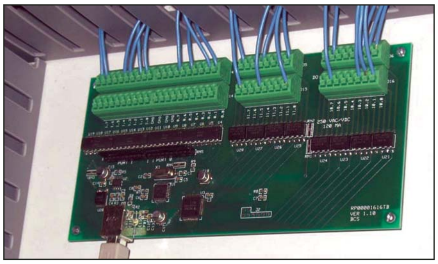

The RP00001616TB buffered USB DIO board features 16 inputs and 16 outputs. Both leads of the optically-isolated inputs are made available to the user. This allows the designer the flexibility to use a variety of DC voltages on the inputs. Each input requires a current limiting resistor and is sensitive to below 2 mA. Two SIP resistor networks are supplied to act as pull-ups for the digital inputs. When the resistor networks are installed, the user can connect the cathode of any of the inputs to the ground supplied on the input connector to signal an input event.

Both leads of each digital output have been made available to the user. Each output has the ability to switch loads up to 250 Vac/Vdc at a maximum current of 120 mA.

This low cost DIO board has an easy-to-use USB interface. The unit is powered by the USB port eliminating the need for external power supplies. Reading and writing the DIO is done through a DLL (dynamic link library). This makes it easy for the popular programming languages (C++Builder, VisualC, Visual Basic, NI's Measurement Studio, etc.) to access the routines needed to control the DIO. This board can also be accessed from an action step in NI's Test Stand using the DLL Flexible Prototype Adapter.

The RP00001616TB buffered USB DIO board is supplied as a PCB, making it ideal for OEM applications. A 10' USB cable, two resistor networks and a CD containing the manual, drivers, and a variety of software examples ships with each unit. The boards are available for $125.

For more information, contact:
BCS
Web: **www.bcsideas.com**

NO PERSONAL COMPUTER NEEDED!

The 20-year habit of requiring a $1,000 personal computer for every $5 computer trainer, logic trainer, or computer educational device can now be broken with a stand-alone microcontroller from Industrial Ventures (IV). The IV Prd Kit has been upgraded to include three meta-technical features:

• Auto message generation including loop-back facility and a complete ASCII-8 character set for testing any standard EIA RS232 device.

• The partially assembled and tested kit with power supply, cables, and instructions insures "out-of-the-box operation" without effort.

• Self-programming Flash memory with the Atmel MEGA8515 RISC microcontroller features 14 MIPS together with operating software including OS, Monitor, and Applications as examples/tutorial.

The IV-Prd-Kit sells for $49, and completely unassembled kits are available starting at $24 each. Shipping is free within the US and begins in June 2006. IV terms are Postal Money Order with order.

Many low-cost accessories and breadboards are available, and pricing and specifications are available from IV.

For more information, contact:
Industrial Ventures
PO Box 245
Waldwick, NJ 07463-0245

■ **LEVEL RATING SYSTEM**

To find out the level of difficulty for each of these projects, turn to our ratings for the answers.

. . . . Beginner Level

. . . . Intermediate Level

. . . . Advanced Level

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A SIMPLE DIGITAL TACHOMETER

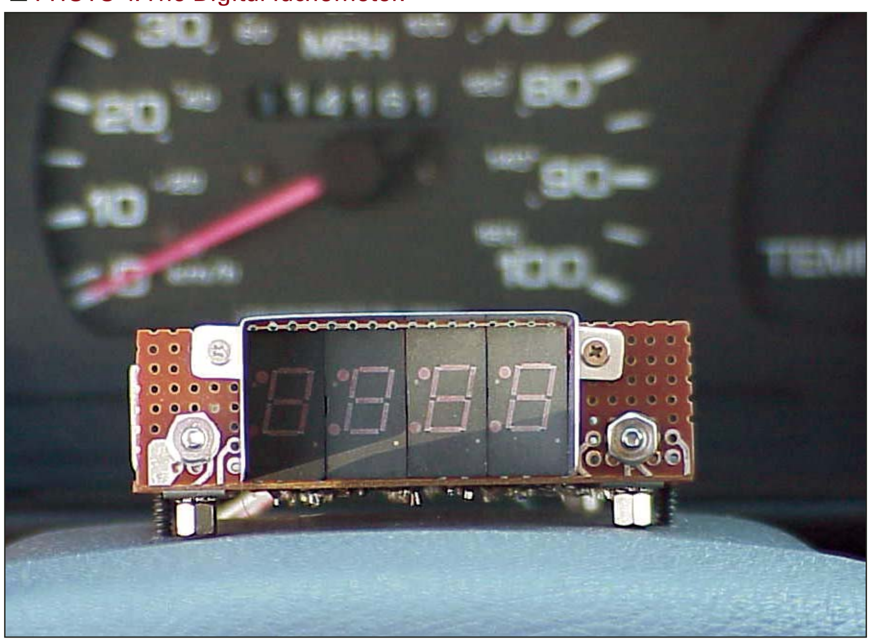
I bought a used Nissan pickup truck a few years back that had absolutely no bells or whistles on it when it rolled off the assembly line. I wanted to make some "improvements" to the engine, and I wanted a tachometer to help assess the results (for better or worse). The add-on tachometers available in auto parts stores didn't appeal to me, mostly because I knew I could make one myself if I put my mind to it.

What I really wanted was a *digital* tachometer.

The circuit would have to satisfy three objectives: it had to be relatively accurate (±100 RPM); it had to be built with parts I already had lying around; and it had to fit on top of the truck's steering column. The second objective ruled out using microcontrollers or multiplexed display drivers — the few of these I have are already in use! With these criteria in mind, I dusted off some TTL databooks, dug through my parts bin and came up with the circuit in Figure 1. The circuit consists of five functional blocks: a Hall-effect sensor; a divide-by-100 counter and latch; a timer to set the count interval; a four-digit display and drivers; and a power supply.

I decided I could live with an accuracy of ±100 RPM, so I could get away with only driving two digits (the two most significant digits, x1000 and x100) to save board space. By doing some simple arithmetic I calculated that counting sensor pulses for 0.6 seconds and multiplying the count by 100 would yield revolutions per minute. Multiplying the count by 100 was accomplished by adding two digits (x10 and x1) permanently wired as "0." This allows the circuit to have a reasonably fast refresh rate while still collecting enough pulses in each 0.6 second window to yield acceptable counting accuracy (for example, the difference

■ PHOTO 1. The Digital Tachometer.



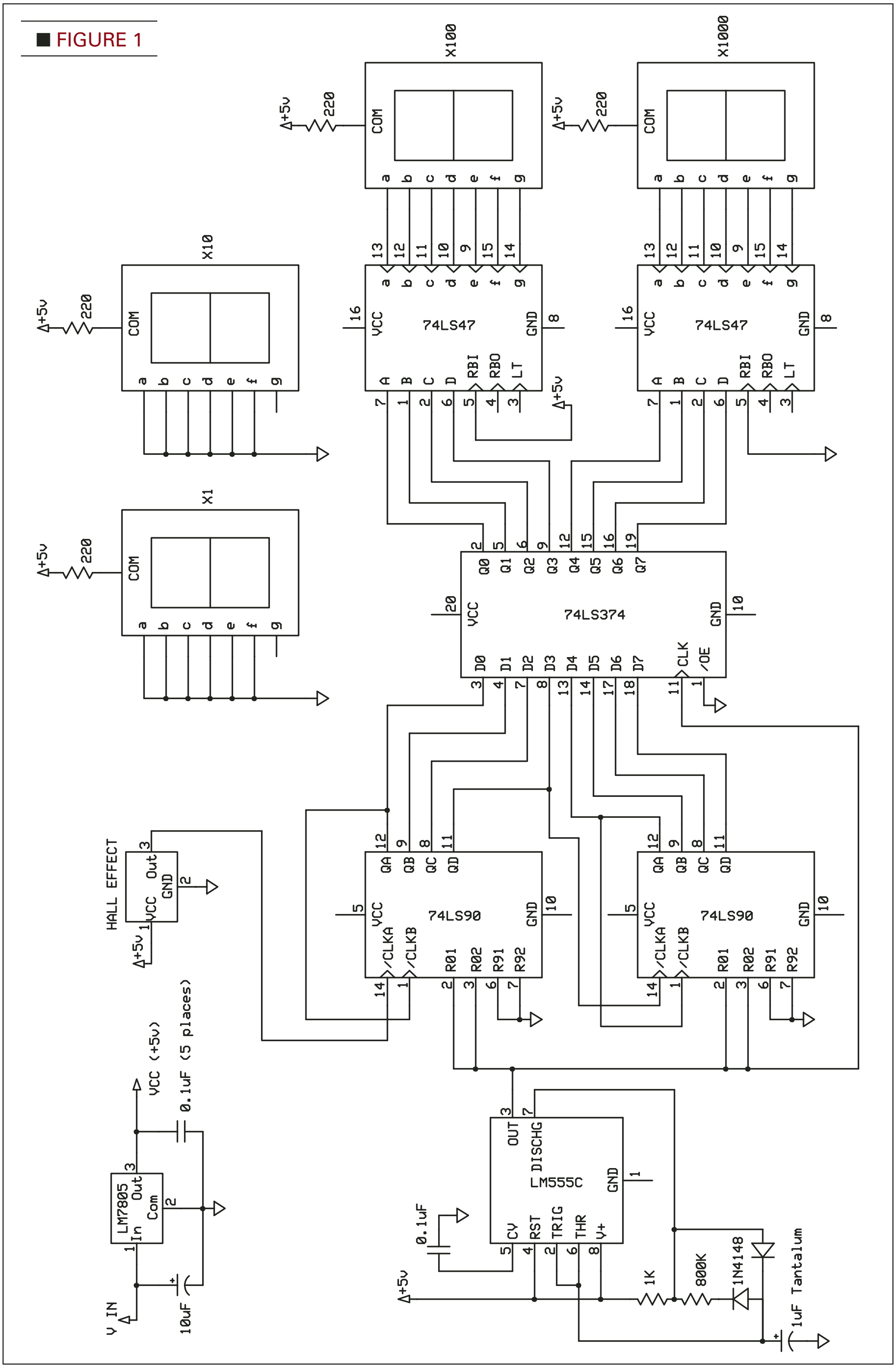
between 19 and 20 pulses is half the percentage difference between 9 and 10 pulses).

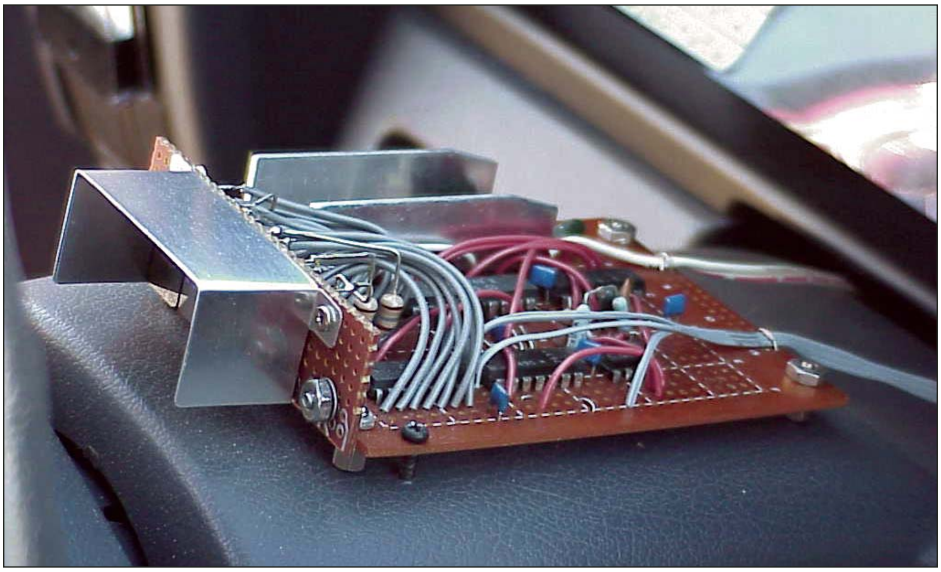
Circuit Design

To count the revolutions of the engine, I used a bidirectional Hall-effect sensor to sense the passage of a magnet I glued to the back of the crank pulley. The sensor I used came from an old floppy disc drive. The response of the sensor is dependent on the orientation of the magnet relative to the sensor. Simply passing the north or south pole of the magnet over the sensor caused it to toggle, but passing the magnet lengthwise over the sensor (so the sensor sees both poles in succession) produced a nice pulse.

The output pulse from the Hall-effect sensor is fed into the CP0 input on the first 74LS90 counter, U1. This counter is wired in a divide-by-ten configuration by connecting output Q0 to input CP1 and by grounding MS1 and MS2. Output Q3 of the first counter is connected to the CP0 input of the second counter, U2, also in a divide-by-ten configuration, which counts the overflow from U1. The binary-coded-decimal outputs from both counters are connected to the inputs of

■ FIGURE 1





■ PHOTO 2. A side view of the digital tachometer.

a 74LS374 eight-bit latch, U3.

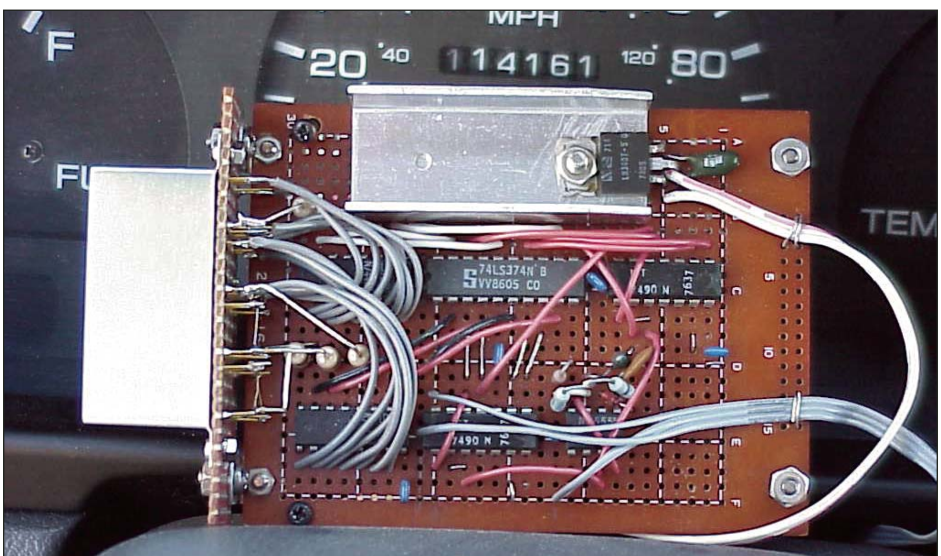
In order for the tachometer (or any frequency counter) to count accurately, it needs a "gate" signal to define the interval during which the counters count pulses. This signal is provided by the 555 timer U4 which is configured to produce a short pulse every 600 ms. The output of the timer is fed to the clock pulse input of the latch and the MR1 and MR2 reset inputs on the counters. The 74LS374 is an edge-triggered device, while the 74LS90 is a level-triggered device, so at the end of each 600 ms interval the count is latched just before the counters are reset. The reset pulse is kept short (a few milliseconds) to minimize the chance of missing a pulse from the Hall-effect sensor. The two diodes allow the timer to operate with this very low duty cycle. A tantalum timing capacitor is recommended for improved frequency stability over a wide temperature range.

The latched count data is fed to the inputs of two 74LS47 common-anode seven-segment LED display drivers, U5 and U6. Data from U1 is fed to the x100 driver U5, while data from U2 is fed to the x1000 driver U6. The ripple blanking input of U5 is held high so that the x100 digit will read "0" when power is first applied. The RBI of U6 is held low to blank a leading zero. As mentioned earlier, the x10 and x1 digits are permanently wired to display "0" by grounding segment inputs "a" through "f." I chose to use a single current-limiting resistor for each display to save space. This causes the display brightness to vary slightly depending on the number being displayed, but the effect is minor as long as low-current displays are used.

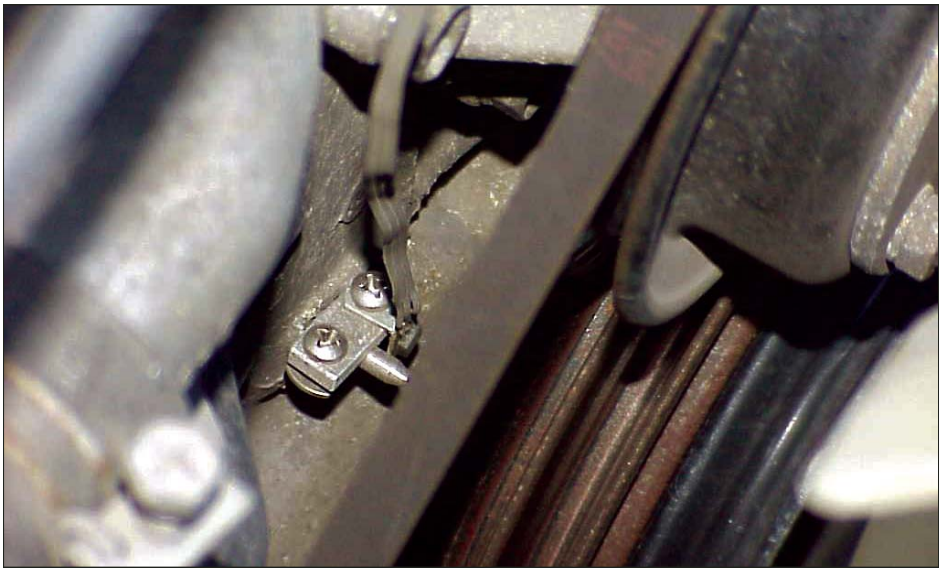
The power supply for the circuit is a standard 7805 linear regulator in a TO-220 package. Since vehicles can produce a lot of electrical noise, you may need more bypass capacitors than the schematic indicates. Ferrite RF chokes may also be needed on the power and sensor cables. I used a total of five 0.1 µF capacitors spread around the circuit board to ensure glitch-free operation. The regulator is dropping 12-14 V down to 5 V, so adequate heatsinking is a must.

Construction and Testing

Circuit board layout is not critical, but the arrangement of the displays should be thought out first. If you intend to mount the tachometer on a vertical surface, the displays can be mounted on the board just like the ICs. If the tachometer will be mounted on a horizontal surface, right-angle sockets mounted on the front of the board simplify display installation. Alternatively, cut another small piece of circuit board, mount the displays on it, and attach the display board to the main board with small right-angle brackets. Make sure the displays are placed in the proper order, with the x1000 digit on the left and the x1 digit on the right. A sun shade for the displays is recommended to



■ PHOTO 3. View of the top of the digital tachometer.



■ PHOTO 4. Here's a look at the tachometer sensor.

prevent them from "washing out" in direct sunlight.

Before installing the Hall-effect sensor, power up the circuit from a clean 12 V power supply and check for smoke. The display should read "000" with the x1000 digit blanked. Apply a 10 Hz squarewave signal to the CP0 input of U1 where the Hall-effect sensor will be attached. The display should read "600" consistently. Next, apply a 100 Hz squarewave signal to the CP0 input, and the display should read "6000" consistently. If the displayed values are stable but incorrect, the values of the timing resistors and capacitor for U4 may need to be adjusted. If the display is erratic or garbled, check your wiring and make sure the ICs are not defective. This is also a good time to make sure the heatsink is sufficient to keep the 7805 regulator cool.

Installation

First, a few words of caution. Installing the tachometer in your vehicle may void your warranty, damage the vehicle, or injure you. *Please* use all applicable safeguards when working on the vehicle, and make sure the key is out of the ignition before proceeding!

Install the tachometer in your vehicle where it is easily visible but does not obstruct any other instruments or controls. Power for the circuit can be obtained from the cigarette lighter socket or any other switched power connector that is readily accessible. Use a three-wire shielded cable to connect the circuit board to the Hall-effect sensor and thread the sensor and cable through an available hole in the firewall, routing the cable away from existing wiring and any hot and/or moving engine components.

Find a suitable mounting location on the front of the engine near the crank pulley and fashion a stable mounting bracket for the Hall-effect sensor to hold it parallel to the back of the pulley. Glue the magnet to a flat surface on the back of the pulley near the outside edge, making sure that the orientation of the magnet is correct to generate a pulse from the sensor as it passes. If possible, use a plastic-coated magnet so that it does not rust, and keep the size of the magnet small to avoid unbalancing the pulley. Make sure that the sensor will not collide with the magnet (or anything else) but is close enough to sense the magnet's passing.

Start the vehicle and check for a reasonable RPM reading on the display. If the display is erratic now but worked fine during calibration, you probably need more bypass capacitors and/or RF chokes on the power supply and sensor leads.

Well, good luck and happy cruising! **NV**

Author Bio

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PARTS LIST

(All available through Digi-Key, 1-800-344-4539)

- ❑ U1, U2 — 74LS90 decade counter
- ❑ U3 — 74LS374 tri-state octal latch
- ❑ U4 — 555 timer
- ❑ U5, U6 — 74LS47 BCD to seven-segment decoder/driver
- ❑ Bidirectional Hall-effect sensor
- ❑ 7805 5 V linear regulator, TO-220 pkg.
- ❑ (4) Common-anode seven-segment LED displays
- ❑ (2) 1N4148 diodes
- ❑ (4) 220 W, 1/2 W resistors
- ❑ 800 k W, 1/2 W resistor
- ❑ 1 k W, 1/2 W resistor
- ❑ 1 µF tantalum capacitor
- ❑ 10 µF electrolytic capacitor
- ❑ Several 0.1 µF ceramic disk capacitors

CHIP MUSIC

COMPOSING SIMPLIFIED

Theory and Practice

"Chip Music" may sound like a new terminology to you, but its meaning is really self-explanitory and it has been around us for a long time.

We all heard the Christmas or birthday songs coming out from various greeting cards. But do you know how to create such music in a tiny chip? Honestly, I didn't — until recently.

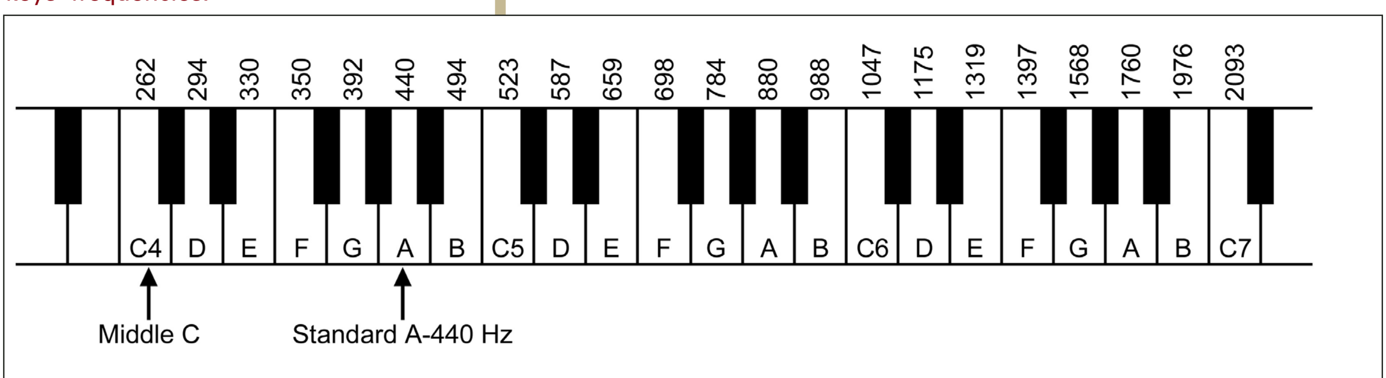
Chip Music Era Has Come

Beginning this year, the prices for some eight-bit micro-controllers have dropped to an unprecedented new low. For example, only 38 cents each for the Atmel's eight-pin ATtiny11 at the quantity of 100 is now available (www.digikey.com). I have been able to purchase Atmel's 8051-like 4KB Flash micro-controller AT89C4051 for only $1.50 each at a quantity of 150 (www.jameco.com).

This is a great phenomenon for us as chip users. Lots of new opportunities are now open to us. What can we do with these opportunities in order to take advantage?

I can't live without music. I can't pass July 4th without singing and hearing *The Star-Spangled Banner*. So, I thought it was about time for me to program some of my favorite music into the chips. Even though I have been accustomed to those songs coming from greeting cards, I never knew how they were programmed.

I decided to try my own way by first learning some basics on music, then starting to write



■ FIGURE 1. This diagram is showing a section of the piano keys and the white keys' frequencies.

musical tone subroutines emulating piano keys' frequencies. The results were very rewarding and exciting. By comparing the standard "A" (440 Hz) tone frequency generated by my "A" Tone Generator program to my piano's A4 key, I noticed for the first time that my piano was a little out-of-tune.

This article is a recap of my recent work. And I hope it will help encourage more people to program their favorite songs into chips. I expect very soon there will be a flurry of chip music booming all around.

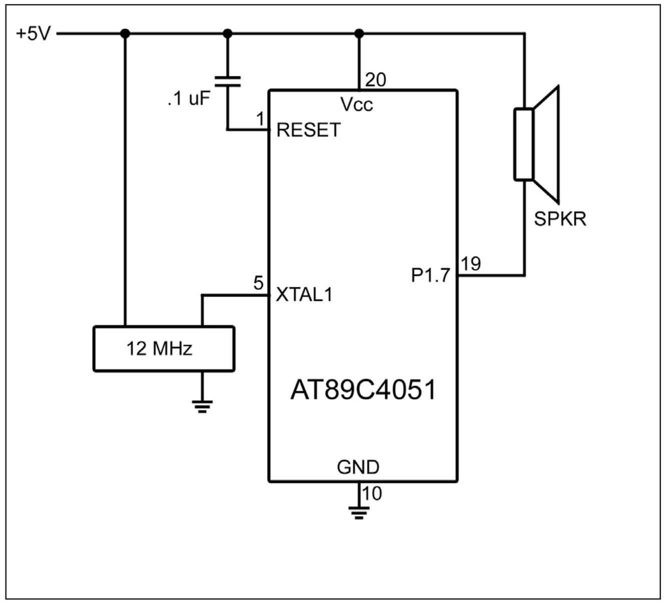
Acoustic Basics of Music

I play piano almost every day, so the natural starting point of music topic is piano. As we know, there are 88 keys on a piano ranging more than seven octaves. The keys within an octave are named by the letters C, D, E, F, G, A, and B. In order to designate a specific key on the piano, we put a subscript number after the letter. Figure 1 shows part of the piano keys and the white keys' frequencies.

The frequency for Middle C (C4 key) is 261.626 Hz, but we can round it up to 262 Hz with no problem, because the human ear can't distinguish tones if the frequency difference is less than 3 Hz.

The standard frequency for musical tuning is 440.000 Hz at the A4 key. This frequency has been adopted as the International Frequency Standard for musical instruments; any other key's frequency can be determined from it. For instance, its higher one octave key A5 frequency is 880 Hz, its higher two octave key A6 frequency is 1760 Hz, etc. And its lower one octave key A3 frequency is 220 Hz, but such low frequency will not be used in our chip music program since most speakers or buzzers won't have good response that low.

■ FIGURE 2. Hardware Configuration.



Music Tone Generation by Microcontroller

Now, let's see how to use a microcontroller to generate the 440 Hz tone. Even though I actually used an eight-pin AVR micro to do it first here, I would like to utilize Atmel's 8051-like micro AT89C1051/2051/4051 for explanation because most people are familiar with it than the other micros, and writing the assembly code for it is just the same as writing 8051 assembly language.

Figure 2 is the hardware configuration for this purpose. In addition to the micro, a reset capacitor, a 12 MHz crystal or oscillator, and a speaker are all we need to form the circuit.

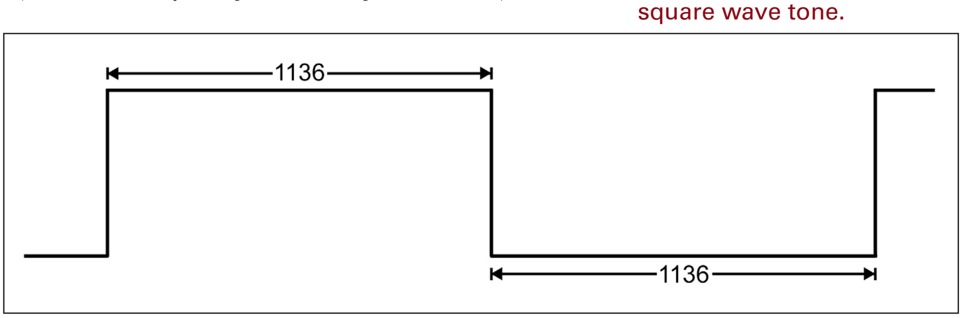
Why do we choose 12 MHz? Because in the 8051, a machine cycle consists of 12 clock cycles, so each machine cycle takes one microsecond (µS) and most 8051 instructions take either one or two machine cycles, so these instructions take either one or two µS. Therefore, calculation becomes very convenient.

The main idea in creating this "A" tone is very simple. A half period for 440 Hz is T/2 = 1/(440*2) = 1,136 µS. As shown in Figure 3, if we apply high/low voltage to the speaker at T/2 alternately, it will generate the required frequency square wave tone.

The entire assembly language program is shown in Listing 1, which is available on the *Nuts & Volts* website (www.nutsvolts.com). As we can see, to get very high accuracy, we create subroutine DL1132 µS; and because setting up a port pin or calling subroutine takes two µS each, the total time for a half period comes to 1,136 µS exactly.

With a good 40 ohm two-inch speaker, and a programmed AT89C1051/2051/4051 microcontroller using my 8x51 programmer

■ FIGURE 3. This diagram shows how to generate the required frequency square wave tone.



References

■ [1] John Backus: *The Acoustical Foundations of Music*, 1977.

■ [2] *Scientific American's Reading Series: The Physics of Music*, 1978.

■ [3] G.Y. Xu: 8x51 Flash/EPROM Microcontroller Programmer, *Circuit Cellar Magazine*, April 1998.

■ [4] G.Y. Xu: Play the AVR HyperTerm, *Nuts & Volts Magazine*, February 2005.

[3], I've found that its tone matches many fine-tuned Steinway and Yamaha pianos. The frequency meter or oscilloscope measurement shows 440.0 Hz. This circuit can be built and mounted in a small box and act like a "Tuning fork" for musicians.

Now, Let's Compose

Just as the words saying "When you know the notes to sing, you can sing (al)most anything." Chip music composing is no difference. Simply put, we need to create the subroutines for each note, then call these routines to make a song. Listing 2 is an example showing how to compose the beginning melody of *The Star-Spangled Banner* (Listing 2 is also available on the *Nuts & Volts* website).

It utilizes only four different notes, but we've created eight note routines for your convenience for future use. Each note routine deals with two parameters: the frequency and the duration of the note.

Using 8051's Timer0 interrupt is the main reason for creating each note routine. As we see, the 8051 works in mode 3, where Timer0 acts as two separate eight-bit counters TL0 and TH0. If the register TL0 is loaded with number 0 to start, it will count up one each microsecond, and overflow after 256 µS.

The necessary steps to enable Timer0 interrupt and start it are shown at the beginning part of the main program. After that, an infinite loop is entered to generate the beginning melody of *The Star-Spangled Banner*.

The principle of frequency generation is the same as on "A" Tone, but the technique is different. Here we deal with a number of different frequencies, not just one like 440 Hz or T/2 = 1,136 µS, and we need to keep the Timer0 interrupt service routine the same for all these frequencies.

A simple solution is to set up the Timer0 so that it always overflows every 8 µS, then calculate how many timer Ticks are needed for T/2 of any frequency we are dealing with.

When counting elapsed time between timer ticks, the time it takes to execute the interrupt service routine, that is, the Interrupt Execution Time (IET) must be taken into account. As calculated in Listing 2, IET=7 µS/INT, so the elapsed time between two ticks is fixed 8+7=15 µS.

Under this scheme the number of ticks for some frequencies may not be an integer and need to be rounded, in such case the calculation can only be approximate. But 8 µS is very small compared to any T/2 we can have, so the created note would still be satisfactory.

Now, let's look at an example from the note subroutine: How many ticks are needed to generate the 523 Hz (T/2=956 µS) tone. Since 956/15 = 63.73, we round it up to 64. But in the note subroutine the tick starts from 0, so it should take 64-1 = 63 as the required ticks. By the way, we have used the note name "Doe" in parallel with "C5" for it; this is helpful in composing.

As for the second parameter, the duration of the note is decided by the number of repeat times Rp for a square wave. Roughly speaking, we can simply assign a fixed number such as Rp = 250 to every note routine. It works, and I did it in my beginning compositions. But this way can't achieve equal duration for every note. The result is the lower the frequency (with larger T/2), the longer the note duration.

A better way to achieve equal note duration is to start from the highest frequency (shortest T/2), assign the largest Rp=255, then calculate the note duration. For instance, in the "C6" note subroutine, the highest frequency is 1,047 Hz, T/2 = 478 µS, if Rp=255 is assigned to it, then the note duration will be

$$Rp * T = 255 * 478 * 2 = 243780\ \mu S,$$
or roughly 1/4 second.

After that, we use this formula to get the required Rp for other lower frequencies. For instance, in the "C5" note subroutine we get

$$Rp = 243780 / T = 243780 / (2*956) = 127.5 \Rightarrow 128$$

By doing so for all other note subroutines, we keep each note duration almost equal to 1/4 second. And we can think of each subroutine call as a "quarter note." This is very helpful when composing; you can estimate the required number of calls for the notes you are going to play.

Last, but not least, we need some delay routines for REST note composing. For example, we already provide 10 milliseconds (ms) and 100 ms delay routines. From there, you can create the "quarter rest" note routine, if needed. Just remember: "half time of all music is silence."

Now that we've created note subroutines, composing *The Star-Spangled Banner* is just a matter of calling the required notes into the main program to construct the melody, as shown in Listing 2. Of course, in order to make a

good song, we need to do it for several iterations, not just once. We need to listen, try, and listen again.

The hardware for playing this song is still the circuit shown in Figure 2, but it is more flexible. For example, you can use 11.0592 MHz instead of 12 MHz, and won't get any unpleasing result. You may also use a buzzer to replace the speaker if space is limited and sound quality can be tolerated.

Build Your Chip Music Library

So far, we've discussed chip music composing only on the 8051, but the principles outlined here can be easily modified and applied to other micros such as AVRs or PICs, as they all have a timer and a similar interrupt scheme.

Once you've created your music files, you need a device programmer to "burn" it on to a micro. For 8051-like micros, there are numerous programmers available on the market, including my 8x51 Flash/EPROM programmer.

With the information presented here, not only you can complete the composing of the remaining portion of *The Star-Spangled Banner*, but also do much more. For example, you can compose Beethoven's *Ode to Joy*. With chip prices dropping so low, it's much easier and cheaper than ever for chip music composing. So don't miss this chance to build your own chip music library as I did.

So, happy chip music composing. **NV**

Author Bio

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A DIGITAL CAPACITANCE METER

Over the years, I have amassed quite a selection of air variable capacitors and trimmers. Starting a project that used one of these devices used to feel like it required an Act of Congress to select the right one, since they were of unknown values.

I finally decided it was time to add a capacitance meter to my test bench.

However, I couldn't justify the cost ($100+), so I decided to build my own.

■The Digital Capacitance Meter.

Reviewing published designs of capacitance meters from the last 20 years, I found that most had flaws that included poor linearity, poor accuracy, and volatile test leads (could blow out internal ICs if shorted together). Some of the designs were superb in resolution and low-end range, reaching well into the femtofarad region. However, their complexity did not justify their extreme accuracy, which was well beyond test-bench needs.

Requirements

At that point, I decided to design my own unit from scratch. My initial prerequisites would be:

- Minimal range switching for an adequate span of measurements
  - No precision components required
  - Minimal adjustments
  - Decent accuracy and stability
  - Battery operation

The completed unit fulfills these requirements. Its accuracy is as good as its resolution will allow and as good as the standard it is calibrated to. Overlap has been provided on all ranges except for the lowest one to help alleviate this problem. It has been my experience that once you get below 10 pF (the worst case resolution here), the physical circuit pretty much dictates the values needed. This is usually the case of adding "a little more or a little less" from the design-center values. Consider this: The average PN junction has a capacity of 5 pF and varies with the voltage across it, making it difficult to predict exactly how it will behave in the finished circuit. Circuit boards and layout can add another 1-5 pF between nodes, which are even more difficult to predict. It is for this reason I decided not to go beyond tenths of picofarads resolution.

The final design then spec'ed out as follows:

- Four ranges:
  - 0-999 pF
  - 0-99.9 nF
  - 0-9.99 µF
  - 0-999 µF
- Four calibration adjustments
- One "zero" adjustment
- No precision components used
- Nine-volt battery operation
- Well beyond 1% accuracy

Theory of Operation

Before I get into construction, I want to give a detailed theory of operation that will also be handy for troubleshooting, if necessary. The heart of this design is U1, an LM311 comparator. Normally the output of U1-p7 is high. When a capacitor is inserted in the Cx test

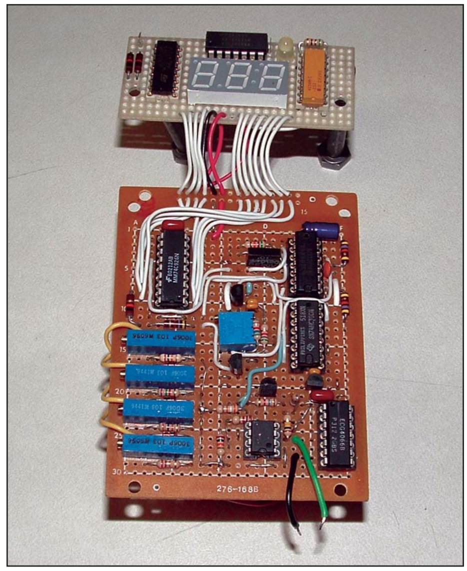
jacks, it begins charging toward the p7 positive voltage through its range-timing resistor (R8, R9, R10). Cx is also connected to the negative input of U1 (p3). When this voltage rises above the reference voltage on p2 (the positive input), the comparator trips and U1-p7 goes low.

Now Cx starts to discharge through the same timing resistance to this new low voltage. The positive input has also immediately dropped to a lower voltage at this time due to feedback resistor R6. U1-p2, the reference voltage, is now lower than Cx (U1-p3 negative input). Cx continues discharging until its voltage drops below the reference of U1-p2. At this point, the comparator trips, the output goes high, and the whole process starts all over again.

Resistors R5 and R6 provide a generous amount of hysterisis for fast switching, stability, and an adequate timing period. R1-R4, in conjunction with P1-P4, provide calibration for each range by setting the proper reference voltage at U1-p2. So basically what we have done is change a physical quantity (capacitance) to an electrical timing signal (period output at U1-p7).

All the component values mentioned so far were chosen to provide a 10.0 ms period at the output of U1-p7 for a full-scale reading on the three-digit display (999 > 000). This equates to 10 µs per count. For example, on the low range (0-999 pF), 1 pF = 1 µs and full scale equals 9.99 ms. This holds true for the first three ranges. Range four (0-999 mF) has a much longer period as will be explained shortly.

When I first constructed this unit, the timing resistors R8-R10 were connected directly to the switch S1B with two inch leads from the board, and I had all kinds of instability problems. This was caused by internal and external noise pickup on these leads. Surprisingly enough, these points were much more noise prone than the leads to Cx. For this reason, U2 (an analog switch) was added to provide switching right at the component location, which totally eliminated this problem. R23,24 ensure their control inputs remain at ground level when not activated. Diode D1 eliminates one switch pole by making S1A do double duty. This circuit is very accurate and linear throughout its range and has infinite resolution since it is basically an analog device.



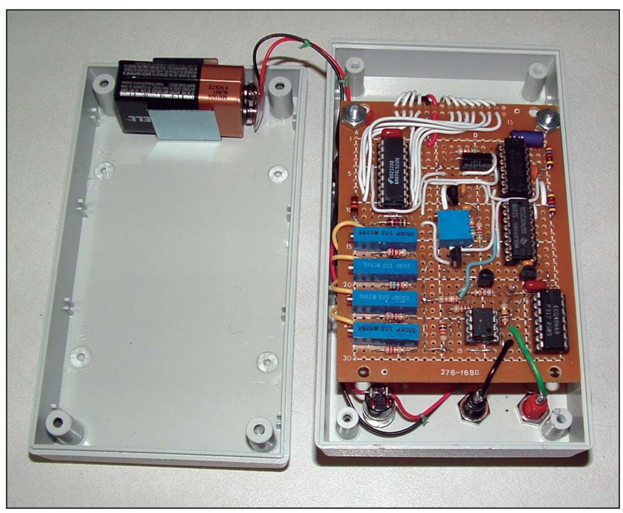
■ The Circuit Boards.

However, there is a price to pay, and that is noise interference. Even a couple hundred microvolts of noise riding on the comparator inputs near the trip points can cause erratic readings on a digital display (wouldn't be a problem with meter displays). But I have incorporated a couple of novel features downstream to almost totally eliminate erratic displays.

The first feature is U3 — a dual decade counter series wired up to give a divide-by-100 function. This, in effect, multiplies the period by 100 (remember that period is the reciprocal of frequency). This is beneficial in several respects. It greatly expands the gating period at its output, allowing not only the display's latched count to hold longer, but also a slower more stable clock frequency (U4C). But above all, it provides 100-period averaging for U1's output, and this greatly improves accuracy and stability in noisy environments.

So, up to this point we now have a period of 1.0 s at U3's output for a full-scale output on the first three ranges. The output is a perfect square wave and the positive going portion will be used as the gate pulse for the clock. On range four (0-999 mF), this divider is bypassed as the time constant requirement for this range is so long that by proper design its gating pulse can go directly to S1C, which selects the proper gating pulse for the range used.

In all cases, we want a 500 ms positive pulse here representing full scale for any range. This gating pulse will drive two circuits from this point. One of these is the circuitry of Q1,Q2. This is a variable delay circuit for zeroing parasitic (stray) capacitance. The positive going edge of the gate pulse is integrated by the combination of R11, P5, C2 before driving the clock oscillator U4A. This delays the start of the clock oscillator which is the second novel feature, as mentioned previously. Instead of merely gating a free running clock oscillator for count



■ Assembled and Open.

pulses, the incoming gate actually starts and stops the oscillator.

When the incoming integrated pulse reaches sufficient amplitude, it instantly starts up the clock oscillator and runs it for that duration. We can get away with a slow rising logic pulse at this point due to the fact that these NAND gates have Schmidt triggers built into their inputs. Also, the clock oscillator can be a one-stage device for the same reason.

By gating the clock in this fashion we eliminate "clock walk through" and its annoying display jitter. "Clock walk through" occurs when the start of a gate can occur at any point in a free-running clock cycle, thereby producing a marching pattern through it. This alternatively affects the display's LSB, causing the "±1 digit" commonly seen in counter specifications. By locking the two together, this is eliminated. U4A is a 2 kHz clock producing 1,000 count pulses in a 500 ms gate period, giving a display of 999 > 000, for a full-scale reading. The clock pulses from here are fed to U5-p12 clock input to operate this device.

Now, let's back up for a moment to the Q1,Q2 delay circuit. This circuit operates only on range one (0-999 pF). We neither need it nor desire it on the other ranges. This is accomplished by turning on Q2 and enabling C2 to ground. Q2 is turned on when the range switch S1A is in the first range by applying +5 V into its base through R13 . Diode D1 isolates this circuit from its associated calibration circuit. C1 provides a small residual delay for the other ranges. Q1 is turned on when the gate pulse goes negative, thereby giving the gate sharp turnoff characteristics and clearing this circuit to ground, setting it up for the next incoming gate pulse. The time constant of R11, P5, C2 determines the level of integration here and hence the amount of delay. P5 now essentially becomes a zeroing control, blocking parasitic capacitance that would otherwise show up on the display. This control has a range of 0-50 pF for zeroing out both internal and external capacitance. This unit will have about 20 pF of internal parasitics to zero out, leaving about 30 more for external parasitics. If desired, P5 could be front-panel mounted, but you will need at least a 10 turn pot for this control.

Returning to the gate output at S1C, when this pulse goes low, U4A stops and the total count is registered in U5's counter circuitry. The negative gate portion fed to U4B is highly

PARTS LIST

RESISTORS	VALUE	SUPPLIER	PART NO.
❑ R1	22K		
❑ R2	33K		
❑ R3	6.8K		
❑ R4	27K		
❑ R5, 14, 18 19, 20, 21 23, 24	10K		
❑ R6	39K		
❑ R7	1K		
❑ R8	100K		
❑ R9	10M		
❑ R10	1.5K		
❑ R11, 12	5.6K		
❑ R13	4.7K		
❑ R15	57K*		
❑ R16, 17	47K		
❑ R22	510		
❑ RN1	330 x 7		
HARDWARE			
❑ S1	Six pole-four pos.	Mouser	10WR046
❑ S2	P.B. NO		
❑ Pin Jacks		Digi-Key	J17-ND, J18-ND
❑ Miniature test jacks		Digi-Key	A-29071-ND
CAPACITORS			
❑ C1	0.003 µF		
❑ C2, C9	0.22 µF		
❑ C3	0.01 µF		
❑ C4, C5	470 pF		
❑ C6	22 µF		
❑ C7	0.1 µF		
❑ C8	0.47 µF		
POTENTIOMETERS			
❑ P1-P4	10K/15T		
❑ P5	100K/15T		
SEMICONDUCTORS			
❑ D1, D2	1N914		
❑ D3	LED five milliamp		
❑ Q1	2N3906		
❑ Q2-4	2N3904		
❑ U1	LM311		
❑ U2	CD4066		
❑ U3	74HC390		
❑ U4	74HC132		
❑ U5	74C926		
❑ U6	ULN2003		
❑ Display	Three digit MX	Digi-Key	160-1545-5-ND

differentiated by the time constant of C4, R16 producing a 20 µs positive pulse at its output. This pulse is fed to U5-p5 and latches its stored count into the display. At the same time, the negative-going edge of this pulse drives U4C through C5, R17 and its operation is identical to U4B. Again, there's a 20 µs positive pulse, but delayed 20 µs from U4B's. This pulse drives U5-p13 and resets the counter circuitry to zero, readying these stages for the next gated counting cycle.

U5 is a four-digit counter with multiplexed output drivers. The last digit (MSB) is not used as we only have a three-digit display. The common segment drivers are current limited through RN1, a 330 Ω DIP package. The common cathodes of the display are driven through U6, a high current, seven-pack inverter.

One annoying feature of the display I used is that the decimal points are also multiplexed. The only way to separate these is with the decoding circuitry of Q3, Q4. If you use a display where the decimal points are individually accessible, you can eliminate this nonsense and run them directly to S1D through suitable current limiting resistors (510 Ω).

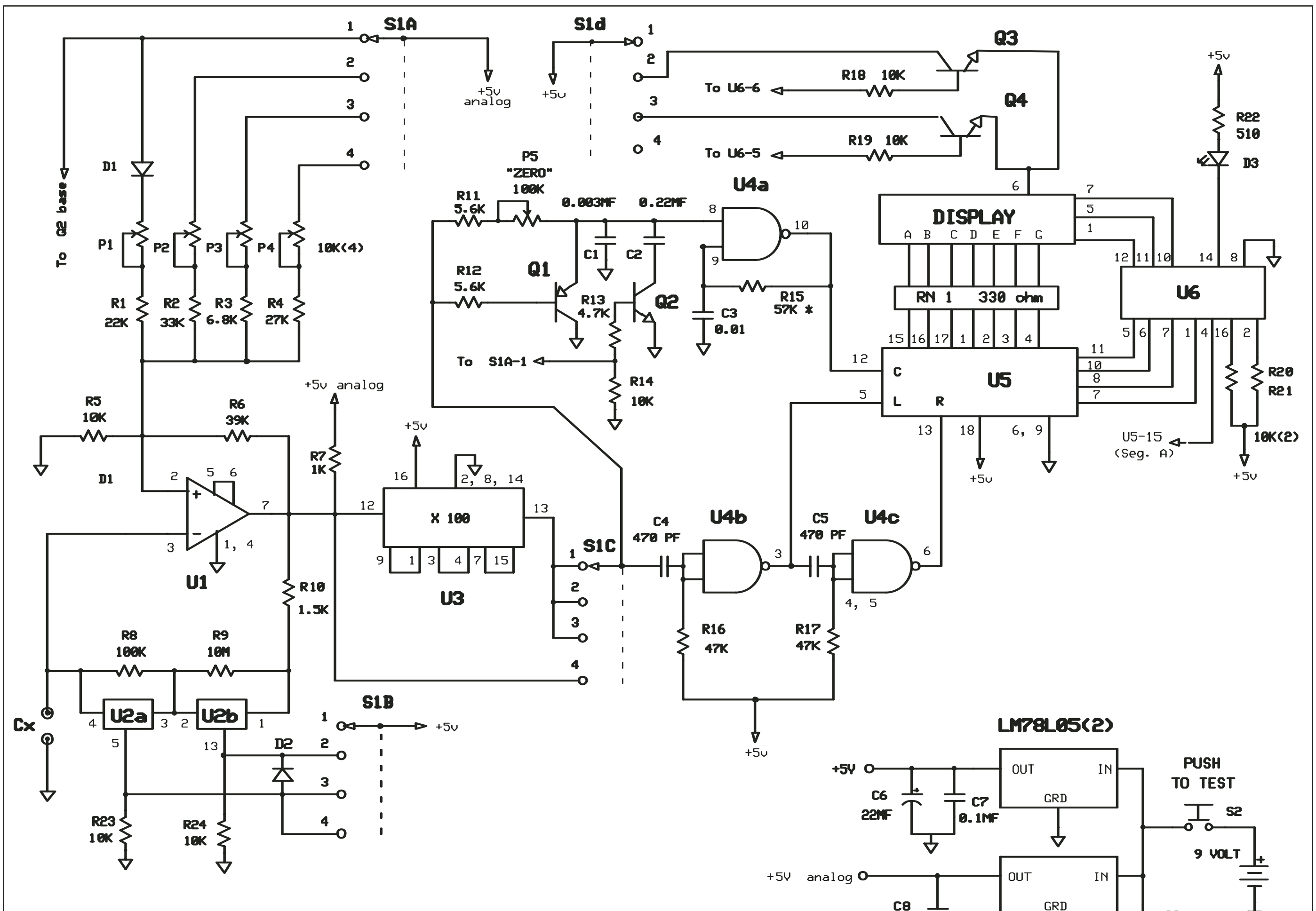
I had neither the room nor the desire to add another chip for overflow circuitry. However, there were three idle inverters in U6 that weren't earning their keep. I wired these up logically to look for a loss of segment "a" at the same time digit "A" was active. Half baked? Yeah, but it does work for the first overflow cycle and takes up almost no additional board real estate. This will at least confirm that when the display reads "000," it's either at full scale or there's no capacitance at all!

You will also note that there are two +5 V supplies. One of these (+5 V analog) is reserved exclusively for the LM311 (U1), which needs very quiet supply lines to operate properly. Although I show one high-frequency bypass capacitor on the supply lines, in practice, I always use several — usually one for every three or four chips and also at the end of long (three inches or so) supply traces.

Construction

At this point, you should have a good understanding of the circuit and the confidence to build it, so now I will go into the construction details.

The circuitry was built on two boards. One was 1-1/4" x 3" perf board,



■The Schematic.

hand-wired for the display, U6, RN1, Q3, and Q4. The other was the main board 2-3/4" x 3-7/8" (RadioShack #276-1688). The display board gets folded back and mounted on the same threaded standoffs as the main board with proper spacers. I used a plastic housing that's common to BUD and SERPAC — available through Mouser.

Once the timing resistor switching (R8-R10) is done, using U2, there is no more critical wiring to do. Just keep U1's Inputs (p2, p3) short and in the clear as much as possible. All the data sheets for the display, chips, and plastic housings are downloadable through Mouser. Mouser has best price on S1. The best price on P1-P5 and U5 (74C926) was from Unicorn Electronics (www.unicornelectronics.com).

The 2 kHz clock oscillator (U4A) can be adjusted to the correct frequency with R15. This does not need to be exact: plus or minus 20 Hz is adequate. Use two resistors here. One will be as large as you can go without going over the target frequency, the other will be a small value to fine-tune it. I used a 51 kΩ in series with a 6.2 kΩ and came within 2 Hz of the 2 kHz target. All resistors are 5% carbon film. R9 (10 MΩ) should be a 1% metal film, not for accuracy, but for its stability. Carbon resistors with this high a value can have wild and unpredictable temperature coefficients. I used a 5% carbon film in this unit but will replace it the next time I have an order going out. These may be hard to find, but Newark Electronics has them.

Once the unit is completed, calibration is achieved by adjusting P1-P4 and P5. The nice feature about these calibration controls is that they compensate for all circuit component tolerances from their design centers including clock frequency error. Start by making a rough adjustment on the high end of each range. Then drop back to range one (0-999 pF) and adjust P5 (zero) to just eliminate any parasitic display to "000." Now readjust P1 to whatever standard you are using. Then adjust ranges two through four to a standard on their high end.

You should now see "000" on all ranges with no capacitance in Cx. If ranges two through four show any parasitic reading, C1 will have to be tweaked somewhere between 2,000-5,000 pF. When making these tests, use the small test receptacles (A-29071-ND that are wired in parallel with Cx's pin jacks) if possible. These will accept lead diameters of 0.20-.40 inches, which will accommodate 90% of tested capacitors. When necessary, use short leads out of the pin jacks and subtract any residual readings that these add (2-10 pF) before connecting the test capacitor.

For calibration, use the best standards you can scrounge up that are near the high end of each range. I am fortunate enough to own a 1% capacitor decade substitution box, but you can purchase a couple of 1% capacitors from Digi-Key that will calibrate the two most critical ranges (one and two). These are 1,000 pF, p/n P3824-ND ($0.63), and 100 nF, p/n P3872-ND ($1.15).

Calibrate, Test, Use

As opportunity presents, you can recalibrate with better standards on ranges three and four. This unit's accuracy is only limited by the accuracy of the standards you calibrate it with. In my case, that was 1%, which is quite adequate for test bench use.

Although the display is quite stable, there will be instances where the Cx value is so close to the next whole digit (i.e., 99%), that it can cause LSB flicker. If that happens, simply move your free hand near the capacitor in Cx (2-3 inches) while reading the display. That will add that last fraction of a picofarad and stabilize the LSB to the next whole digit that it is already so close to.

The average current draw on this unit is about 35 mA, which is a pretty hefty load for a nine-volt battery. I ran accelerated life tests, assuming 1,000 tests per year at five seconds per test, and it appears the battery would last almost as long as its shelf life. For the front panel, I tried something new. I drew this up from one of my schematic CAD programs, along with text. I then printed this out on glossy photo paper and pasted it to the case with spray adhesive. Looks nice, but I don't know how durable it will be. Time will tell, I guess. I built this unit for less than $30 and am very satisfied with it. The first tests I performed were to quantify and label all those air variable capacitors and trimmers. It was a breeze and a joy. **NV**

ELECTRONET

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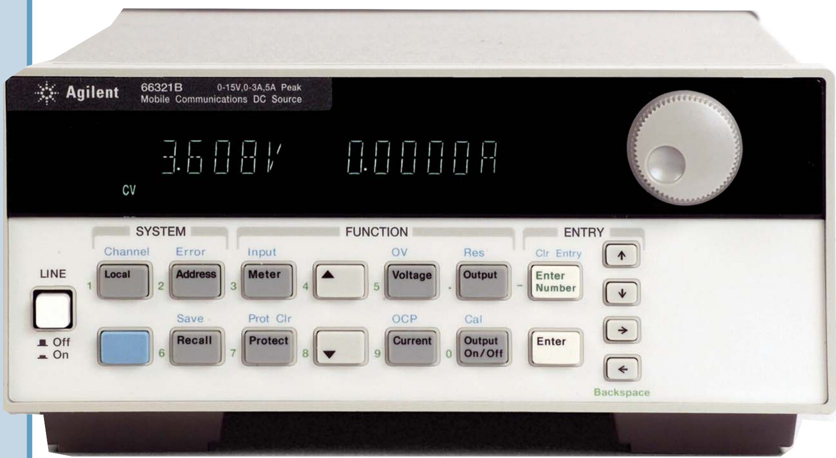
CONSTANT CURRENT SOURCES

by Vaughn D. Martin

PART 2

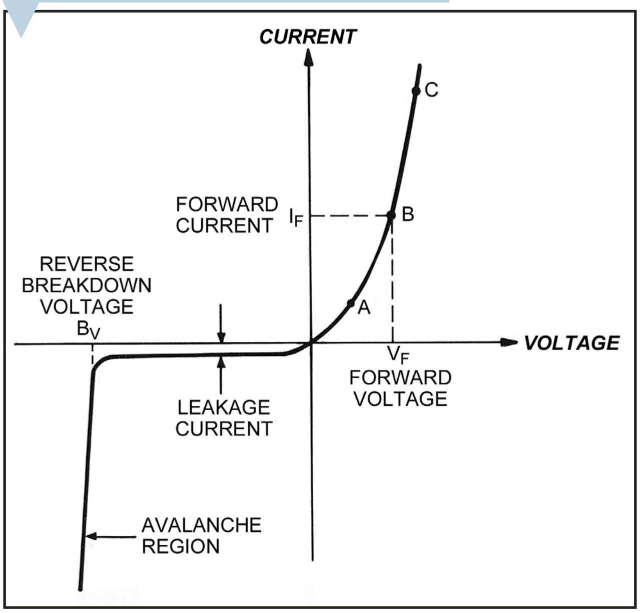


Part 1 explained what a constant current source (CCS) is and examined applications in four-point measurements, resistance testing, electrical-contact testing, and temperature measurement using the DR (change in resistance) method. Now we'll conclude with semiconductor, electrical component, and finally electrochemical applications.

Acknowledgements

I wish to thank the following individuals for help with this article. Mike Kirk of Agilent and Dr. Mike Lauderbach of LeCroy gave technical assistance and supplied artwork, and Juan Moore of Tektronix also supplied artwork.

Figure 1
Characteristic V-I curve for a P-N junction diode.



Semiconductor Device Measurements

A CCS is ideal for testing current-controlled devices, particularly breakdown voltages of transistor junctions, since manufacturers specify breakdown voltages at a constant current. And small-signal H-parameter measurements require you to supply the transistor with a constant DC bias current upon which you superimpose AC modulation (see Table 1).

However, you cannot measure all semiconductor parameters with a CCS. Collector leakage current (I_{CEO}) and emitter-base cutoff current (I_{CBO}) require a constant *voltage*, which is difficult for a CCS to supply. Even if you could measure these parameters with a CCS, their currents are Lilliputian (for small signal transistors, I_{CEO} is usually less than a microampere, and I_{CBO} is often only a few nanoamperes).

Diode Forward Voltage Drop

Let's begin simply by measuring a diode's forward voltage drop. Figure 1 shows a typical diode's (P-N junction) characteristic. Manufacturers' data sheets usually specify the maximum forward voltage drop, V_F, at several forward currents, I_F. Figure 2 shows the setup. Note that different forward

Parameter	Alternate Symbols	Definition	Typical Value
h_{ie}	h_{11}, r_n	Input impedance (v_{be}/i_b), output short circuited.	2 kilohms
h_{re}	h_{12}, μ	Reverse voltage amplification factor (v_{be}/v_{ce}), input open circuited.	5×10^{-4}
h_{fe}	h_{21}, β	Forward current gain (i_c/i_b), output short circuited.	100
h_{oe}	h_{22}, g_o	Output admittance (i_c/v_{ce}), input open circuited.	10μmhos

Table 1. Definitions of small signal transistor H-parameters.

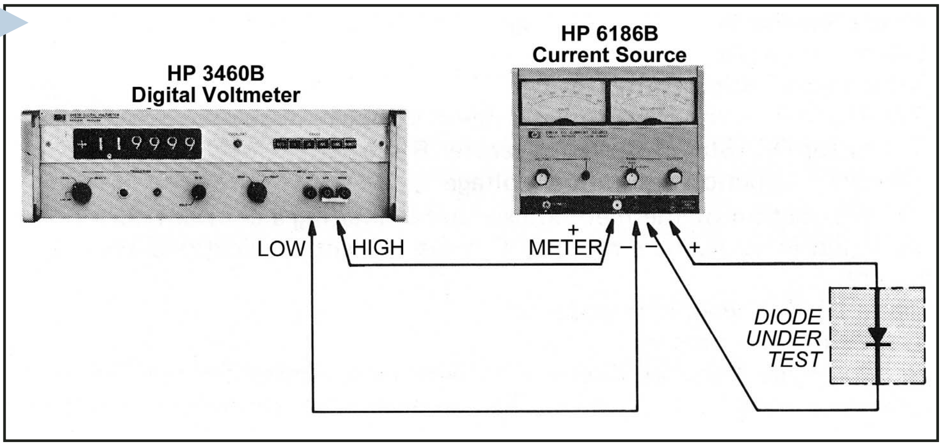


Figure 2
Basic set up for measuring the characteristic V-I curve for a P-N junction diode.

currents move the measuring point along the characteristic curve points A, B, and C in Figure 1.

Diode Reverse Breakdown Voltage

Manufacturers' data sheets specify a diode's minimum reverse breakdown voltage (B_V) at a fixed reverse current. As with forward voltage drops, you measure this parameter by simply applying a constant current through the diode in the reverse direction and measuring its voltage drop. The setup shown in Figure 2 is the same as for measuring the forward voltage drop; just reverse the diode.

You are *non-destructively* measuring "breakdown" voltage when you use a CCS for this test. The breakdown voltage in Figure 1 is at the beginning of the avalanche region. Large changes in reverse current in this region result in only very small changes in reverse voltage. If you were using a constant voltage source, a very small change in output voltage would increase the reverse current (and power dissipation) until the diode failed. By using a CCS, however, you control *current* as the variable, not *voltage*.

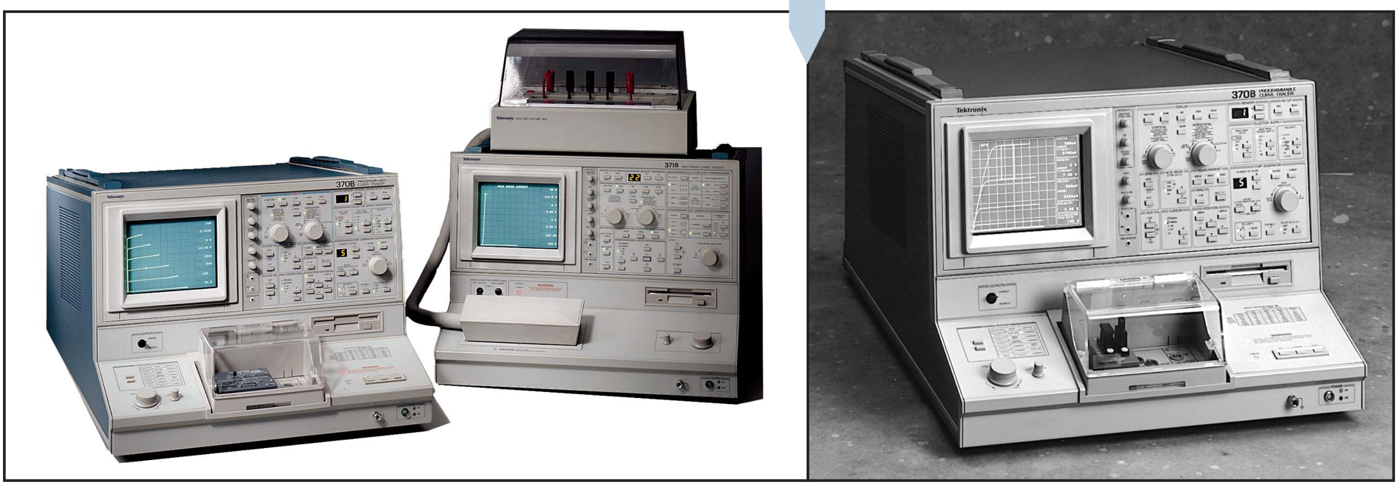
When you make the measurement, vary the diode's current to move the operating point as in the forward voltage measurement example, but in the reverse direction. Since the leakage current — see Figure 1 again — is so small (often less than one microampere for silicon signal diodes), you will rapidly cross the almost-horizontal portion of the characteristic as the output of your CCS increases from zero. Increasing the current output above several microamperes causes the measured reverse voltage to increase very slowly. When you observe this, it definitely indicates that the diode is operating in the breakdown avalanche) mode.

You can measure zener voltage with this same procedure, since zener voltage is simply the reverse breakdown voltage of a diode *designed* to be operated in the zener or avalanche region. Manufacturers' data sheets usually specify this parameter either at the test current that dissipates 25% of the maximum rated value for non-temperature-compensated zener diodes, or at the current causing a minimum voltage temperature coefficient for reference (temperature-compensated) zener diodes.

Diode Temperature Coefficient

Using a temperature-controlled oven, repeat the procedures for determining the forward (or reverse) voltage temperature coefficient of a diode (or any other component). Place the diode in the oven (the CCS is outside the oven) as shown in Figure 2, and vary the temperature over your desired range. Record the voltage at each desired temperature setting. Allow enough time for the diode junction temperature to stabilize before taking another voltage reading. The forward voltage temperature coefficient of silicon signal diodes is typically 2 mV/°C. Typical temperature coefficients of

Figure 3
Tektronix' fully-programmable 370B and 371B digital curve tracers for characterization and test of semiconductor components.



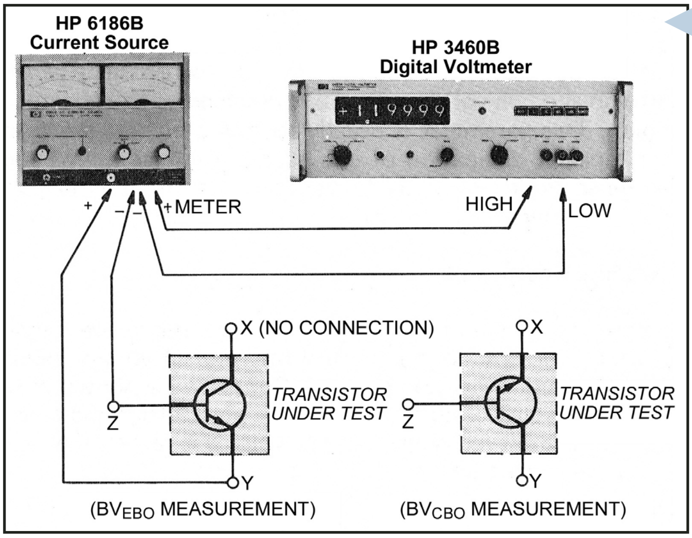


Figure 4
Test set up for measuring transistor collector current breakdown voltages BV_{CEO}, BV_{CER}, BV_{CES}, and BV_{CEV} (in ascending order), see switch position.

zener voltage vary from 25 mV/°C to essentially zero for reference diodes.

V-I Characteristics of any Semiconductor

You can capture the entire V-I characteristic of any semiconductor device, linear or non-linear. Using the methods described above of supplying a known current and measuring voltage drop across the device, take measurements at numerous current levels. Instead of measuring two specific points on the characteristic of e.g., a transistor, you can remotely program a CCS's meter terminal and connect it to your PC. There are commercially available programs that will dump this collected data into a spreadsheet and render a colorful plot. You'll then have the basis of a semiconductor curve tracer, similar to the sophisticated Tektronix models shown in Figure 3.

Transistor Junction Reverse Breakdown Voltage

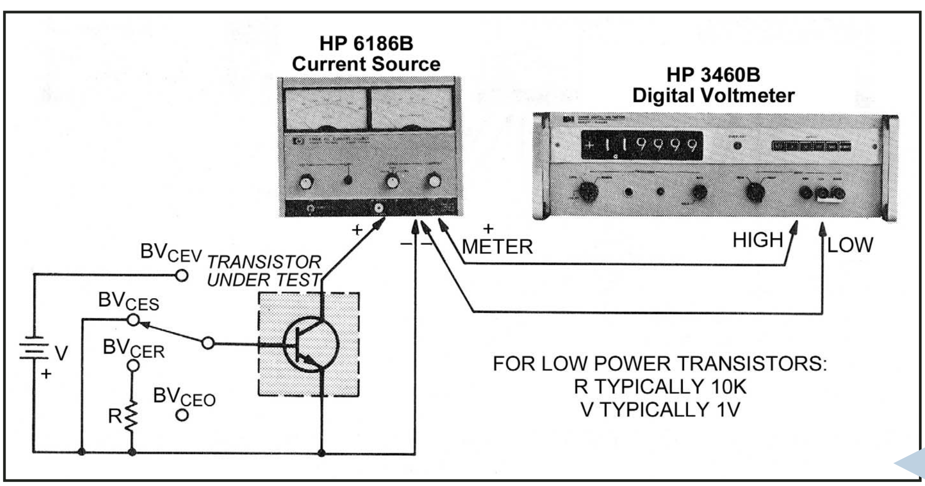
For a transistor junction (e.g., the base-emitter junction), you can measure the breakdown voltage as for a diode. Transistor data sheets specify BV_{EBO}, the emitter-to-base breakdown voltage with the collector open, at a constant current (typically 100 µA). You can set this current on your CCS, and the breakdown voltage (typically less than 10 V for low-power silicon transistors), and read it directly from the voltmeter connected to the meter terminal on the CCS. Similarly, you can measure BV_{CBO}, the collector-to-base breakdown voltage with the emitter open. Typical values vary with devices selected for specific applications.

The most common breakdown voltage is the collector-to-emitter value. There are four different collector-emitter breakdown voltages that you can measure, depending on the base connection. In order of increasing magnitude, these are: BV_{CEO} (base open), BV_{CER} (base connected to the emitter through a resistor of value R), BV_{CES} (base shorted to the emitter), and BV_{CEV} (base reversed biased with respect to the emitter by voltage). Figure 4 shows a simple setup for determining these voltages. Manufacturers usually specify these breakdown voltages at a higher collector current than the BV_{EBO} and BV_{CBO} specifications, typically 1 mA, in order to avoid problems with leakage-current multiplication.

Transistor DC (Static) Current Transfer Ratio

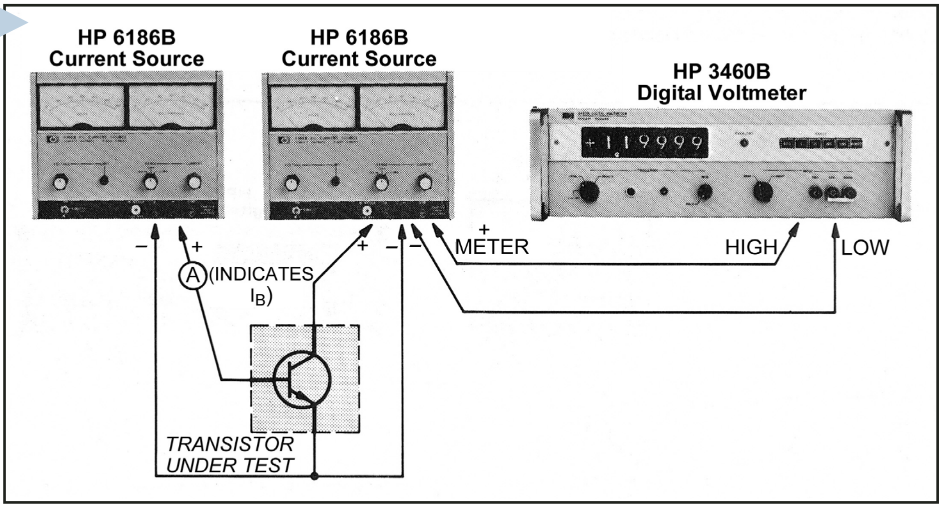
The most frequently used transistor parameter is the forward-current transfer ratio. This ratio measures a transistor's gain (amplification factor). Manufacturers commonly specify this ratio for two different transistor connections: common emitter and common base. You can easily measure both using a CCS. This section describes the common-emitter transfer ratio (h_{FE} or β) and the common-base transfer ratio (h_{FB} or α).

You can measure these on either a qualitative or "pass-fail" basis. Both use virtually the same test setup, shown in Figure 5. In both cases, CCSs supply the base and collector current for the transistor. On transistor data sheets, manufacturers usually specify β at given collector currents and collector-to-emitter voltages. Therefore, you need to set the collector current for the specified I_C, and adjust the base current until V_{CE} (displayed by the voltmeter connected to the meter terminal of your CCS) reaches the specified value. You first measure the current supplied from the base CCS, then you calculate β by dividing the set collector current by the base current



Test set up for measuring transistor common emitter DC current transfer ratio and junction saturation voltage.
Figure 5

Figure 6
Test set up for measuring potentiometer effective running resistance.



you measured.

For small signal transistors, I_C is typically 1-2 mA, and β ranges from 20-400. For a typical β of 100, the base current will be 10-20 µA. But this is too small for you to read accurately from the CCS' front panel meter. You must measure this current with either a series ammeter (see Figure 5) or a small current-monitoring resistor and a voltmeter. "Pass-fail" measurements are more suited to production environments, but can follow this procedure too. The collector-to-emitter voltage then becomes the measured variable. If the V_{CE} you read on the meter is less than or greater than the test specification, β is greater or less than required, respectively.

Transistor Junction Saturation Voltage

$VCE_{(SAT)}$ is the voltage from the collector to the emitter for a given I_C and I_B while biased in the collector saturation region. The measurement of this parameter uses the setup in Figure 5. Set the specified base and collector currents on the CCS and read $VCE_{(SAT)}$ directly from the voltmeter connected to the CCS' meter terminal. Typical values of $VCE_{(SAT)}$ for small-signal silicon transistors range from 0.1-0.5 V.

Component Testing

Electrolytic Capacitors

Electrolytic capacitors are difficult to measure due to their effective series resistance. This resistance is dominant at higher frequencies, making an AC bridge measurement almost useless. The Capacitance sidebar gives the definition of a capacitor.

If you apply a constant current to a capacitor, the measured time for the voltage across the capacitor to rise from zero to its rated value is proportional to the capacitance. (An ordinary DC power supply would not supply a constant current, but rather an exponential one! Therefore, it would charge the capacitor according to the well known RC time-constant pattern in which, after five time constants, the capacitor would be over 99% fully charged.)

Before you make this measurement, operate the capacitor for a few minutes at its rated voltage to insure that it is well formed, then short circuit it with a 1 kΩ resistor to ground for at least 30 seconds. This minimizes leakage current in the capacitor during the value measurement charging cycle. The long discharge period guards against polarization that often results in slight "re-volting" after a short-duration short circuit. Depending on the value and rated voltage of the capacitor under test, and the magnitude of the applied current, the measured time can vary from 1-60 s. Using the equation in the Capacitance sidebar, with a 2,000 µF, 50 VDC electrolytic capacitor and a current of 1 mA, the interval would be (2 x 10^{-3} F x 50 V) / 10^{-2} A = 10 s.

Relays and Analog Meters

Pull-in and drop-out currents are important values for relays. These current values, normally specified at room temperature, take on added significance at elevated temperatures because they may be significantly different due to changes in coil resistance. You can determine these values by noting the *constant currents* at which the relay armature pulls in and drops out. The former value is always higher than the latter.

You can perform four tests on analog meters using a CCS: (1) accuracy, (2) movement freedom, (3) mid-scale linearity, and (4) temperature coefficient. First, you can use a CCS to accuracy measure and calibrate meters. Second, you can slowly vary this constant current from zero to the full-scale value and sweep the pointer over the entire scale, ensuring the meter movement does not stick or encounter other mechanical difficulties. Third, you can set the meter to exactly full scale with a CCS and then reduce the current by exactly half, to check mid-scale linearity. Finally, you can check the temperature coefficient with a temperature-controlled oven.

This last parameter is a function of the wire used in the movement coil. Typically, meter coils are wound with copper wire having a temperature coefficient of approximately 4,000 ppm/°C. You can also perform all of these — except (2) — on digital meters, as well.

Capacitance

Definition of a capacitor: *A capacitor has a value of one farad when a voltage change of one volt per second across it produces a current of one ampere.*

I = C ΔV / ΔT, that is, one ampere = one farad times the change in voltage divided by change in time

Oscilloscopes

Most oscilloscopes can only measure single-ended voltages referenced to earth ground. Internal probe wiring connects the reference lead to the BNC's shell. This ensures the scope probe's reference lead is electrically common to the scope's chassis. The power cord's ground conductor further connects the chassis to earth ground. In most measurement applications, single-ended measurements are acceptable, but not always.

Measuring voltages that are not referenced to ground, such as the voltage across the switching device in a switching power supply, is an application requiring differential measurements. Examples include balanced signals requiring equal impedance source and return paths. Applications include telephone lines, read channels in magnetic-storage systems, and some digital-communication systems. To dramatically demonstrate this, we'll make a measurement not involving ground — a true "differential" measurement!

Sometimes, you should make differential measurements even of ground-referenced signals. Because the scope-probe reference lead is grounded, attaching it to a circuit creates multiple ground paths, otherwise known as a ground loop. Magnetic fields radiate from current that passes through circuit conductors. Passing these currents through the ground loop induces circulating currents in the loop. These currents can interfere with the circuit operation and corrupt measured waveforms.

Potentiometers

Obviously you can check the basic resistance value of a potentiometer, but the effective running resistance (wiper noise) is another, more specialized, parameter. This parameter is the contact resistance of the wiper touching the resistance element. Figure 6 shows the setup. Apply a constant current through portion "A" of the potentiometer, producing a voltage with respect to ground (seen at the "plus" input to the horizontal amplifier) that has magnitude proportional to the sum of the "A" portion resistance and the wiper contact resistance. The "minus" input of the horizontal amplifier sees only the voltage drop across the wiper contact resistance (note that no current flows through the "B" portion of the potentiometer). Subtract this voltage from the voltage at the "plus" input by virtue of the differential input, leaving a voltage applied to the horizontal deflection plates that is proportional *only* to the percent rotation of the potentiometer.

The single-ended vertical amplifier, connected to the horizontal "minus" input, also sees only the voltage drop across the wiper contact resistance. The resulting display on the oscilloscope screen is a spot that moves horizontally as you turn the potentiometer clockwise, and vertically in proportion to the effective running resistance.

Select amplifier sensitivities that will keep the spot on-screen. For example, for a horizontal deflection of 10 cm with an applied current of 1 mA, the horizontal amplifier should be set to (0.1 V/cm) / 1 kΩ of potentiometer resistance. Since a vertical deflection of 5 cm is equivalent to an effective running resistance of 25 Ω, the vertical amplifier, in this case, should be set to 5 mV/cm.

Potentiometers

A potentiometer (pot) is an electro-mechanical transducer. As you rotate it, a change of resistance occurs. With connections only at one end and its wiper, it is a rheostat — or essentially a variable wire-wound resistor. Historically, variable resistors emerged as either blocks of carbon (or other resistive material) with a sliding contact. Modern pots have 270 degrees of rotation. Connections on both ends and the wiper constitute a true pot configuration.

A pot's taper is crucial. The vast majority of pots are linear, that is, if you rotate them one-third of their total rotation, the change in resistance will likewise be one-third of its total resistance. However, there are non-linear or "logarithmic" tapered pots. These are used, for example, in audio applications, because our ear has a logarithmic response to sound pressure. A stereo's volume control should provide a smooth transition from soft to loud, and that's what an "audio tapered" pot gives you.

A pot also has a dielectric rating that is a measure of the insulation of the pot's "internal works" to its body. This becomes crucial if you connect the pot to an AC wall outlet with non-isolated equipment. An example of this is an AC lamp dimmer. The dielectric rating for a pot connected to an AC outlet should be at least 3 kV.

Other Applications

Constant current and electrochemistry are related by Faraday's laws of electrolysis. Simply stated, these are:

1. The amounts of primary product formed by electrolysis are directly proportional to the amount of electricity flowing.

2. The passage of a given quantity of

Resources

1 **www.evaluationengineering.com/archive/articles/0396wafr.htm** is an excellent explanation of Low-Current Probing, as required with submicron device technology ICs today.

2 **www.mt.com/mt/resourcedetail/articles.jsp?m=t&key=E3Mjg4NjM1Mz** is an excellent source on coulometric titration.

3 **www.epsilon-web.net/Ec/manual/Techniques/CPot/cp.html** is an excellent introduction to chronopotentiometry.

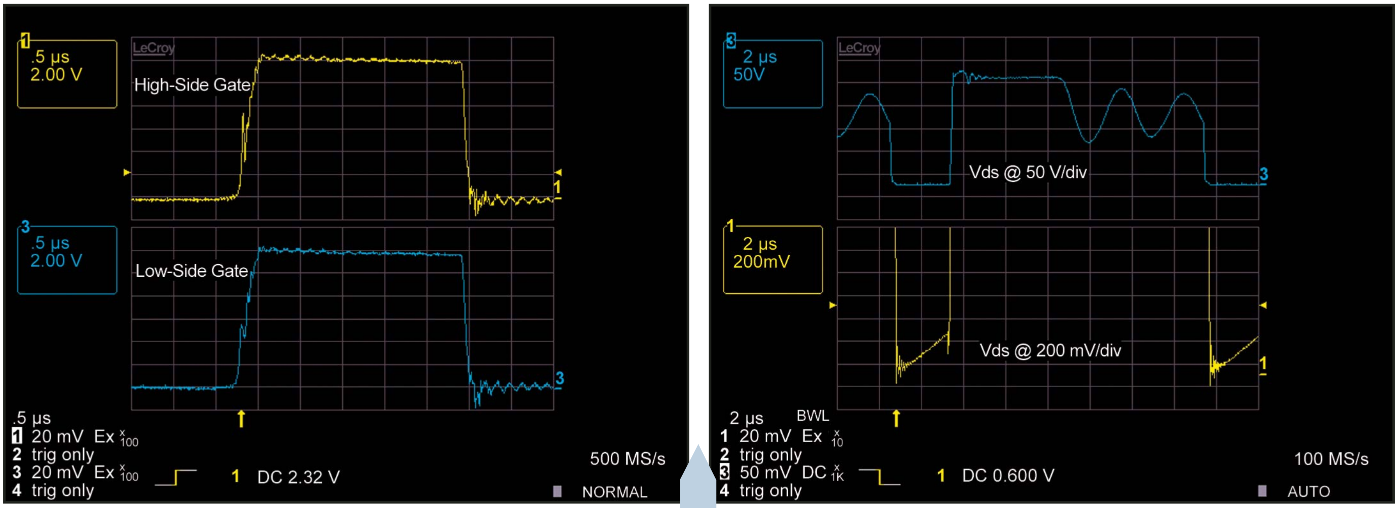


Figure 7
Oscilloscope amplifiers and passive probes are not precisely matched for higher frequency gain (or attenuation), and there are no provisions for fine adjustment of DC attenuation or precise alignment of time constants (AC compensation), CMRR above a few kHz will be very low. Measurements such as high-side gate drive measurements become impossible in high common mode voltage situations. The figure on the left shows the high side gate measured without a differential amplifier, the figure on the right catches the "ringing" by virtue of the differential amplification of the entire signal.

electricity causes the amounts of primary products formed by electrolysis to be in the ratios of the chemical equivalents of those products.

The basic unit used for "amount of electricity flowing" is the coulomb. One coulomb is a current of one ampere flowing for one second. The *current* is the parameter of interest in many electrochemical processes, and a precision CCS makes precise current control very simple.

The most common electrochemical process using constant current is coulometric titration[2]. This analytic procedure involves removing one constituent of a solution by quantitative electrolysis. It measures the amount of a substance in a solution by measuring the number of coulombs (current magnitude times elapsed time) required to completely titrate the solution. One limitation of this procedure is that it must be 100% current efficient: all the current passing through the cell must be converted into electrolytic product with no losses.

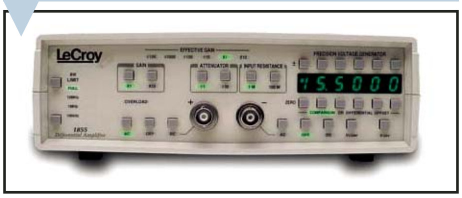
Electrogravimetry and precision electroplating are two other electrochemical applications using constant current. The former process, similar in end result to coulometric titration, is a method of analytically determining the amount of a substance in a solution by deposition onto a weighed electrode. In the latter process, you plate an electrode (such as that used in a pacemaker's implanted catheter) with a thin metal film of precisely known thickness.

Additional applications of constant current in the electrochemical laboratory include chrono-potentiometry[3] (a mass transfer technique for determining the concentration of a substance in a solution) and electrode kinetics (the study of the actual atomic mechanisms of electrochemical reactions). **NV**

Electrogravimetry

Electrogravimetry is an interference-removal technique using two or three electrodes. You apply a constant current to the pre-weighted, working electrode and this electric current deposits a solid onto an electrode from solution. Normally, the deposit is a metallic plate formed by metal ions in the solution.

Figure 8
LeCroy DA1855A differential amplifier.



LeCroy DXC100 differential probes.
Figure 9

Digital Storage Oscilloscopes

Digital Storage Oscilloscopes (DSOs) are virtually the only scope manufactured today, yet they lack Z-axis (intensity) modulation and the ability of analog scopes to make the differential measurements that Figure 7 requires. LeCroy, a leading DSO manufacturer, addressed this problem with a differential amplifier and probe (see Figures 8 and 9). The DA1855A is a stand-alone, high-performance 100 MHz differential amplifier. It acts as a signal-conditioning preamplifier for oscilloscopes and network and spectrum analyzers by providing differential measurement capability to instruments having only a single-ended input.


Cutting edge products to quickly solve your toughest design and measurement problems!
Polystyrene Caps
EXFA - precision polystyrene Caps for ultra-low loss, excellent stability. 47 – 8200pF. Great for audio, no need to redesign existing products! Better than teflon, polypropylene. less than $1!
RH-02 / PT104
RH-02 - Temperature and Humidity Logger for PC. PT104 - High resolution and accuracy. Platinum sensors. USB powered - no power supply required. Free s/ware. from $320.99/643.60!
Touch-sensing ICs
Quantum ICs- World-beating capacitive sensor ICs for switching and control with patented features like Adjacent Key Suppression, Spreadspectrum, adjustable sensitivity. QRG ICs in use worldwide by the world's largest consumer/appliance manufacturers <$1 (10K)
Universal Meter
Unimeter - User-configurable datalogger/controller/meter with built-in real-time math calculations. 100s of uses: process control, logger, 5 digit LCD, bargraph, A/D, I/O. Unimeter $399
USB to 24 x I/O
USBI/O24 - 24 latched I/O lines self-powered from your PC's USB port. Ubicom SX52 allows individual pin I/O programming. I/O control via PCs USB port. USB I/O 24 from $69!
USB-inSync Logger
DAQ-2500X - Synchronizable USB 4-channel 100kS/s data acquisition. Expands to 16 channels with programmable I/O for process control, alarm, etc. DAQ-2500X $1195
FATfile Storage
ALFAT-SD - easy, ready-made way to add SD storage to your product. Serial data in/FATfile data out. - $49.95. Or design-in an ALFAT ic for MB storage - $24.95 ea.
Mini Web Server
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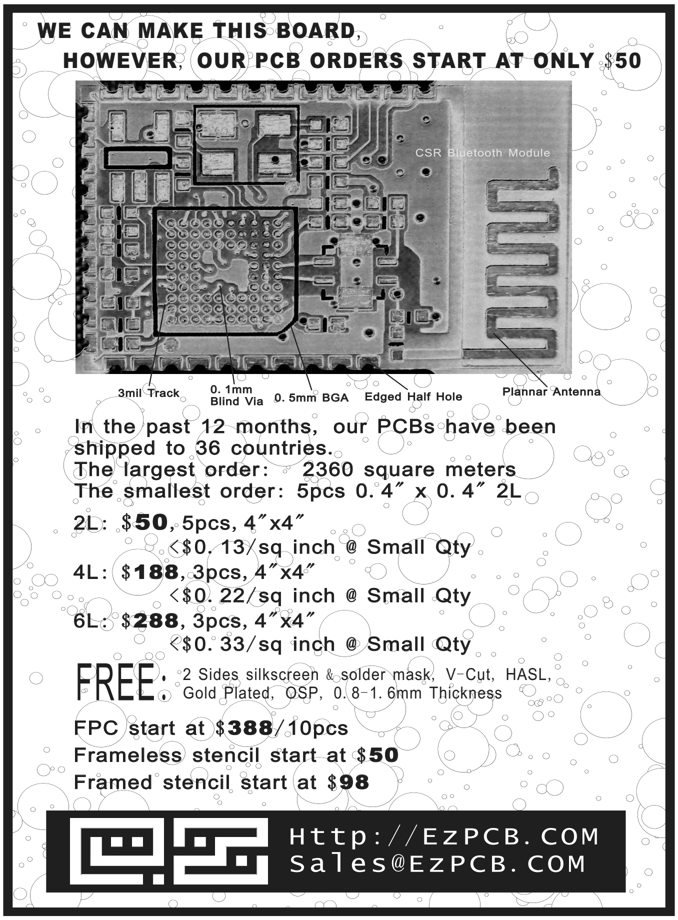
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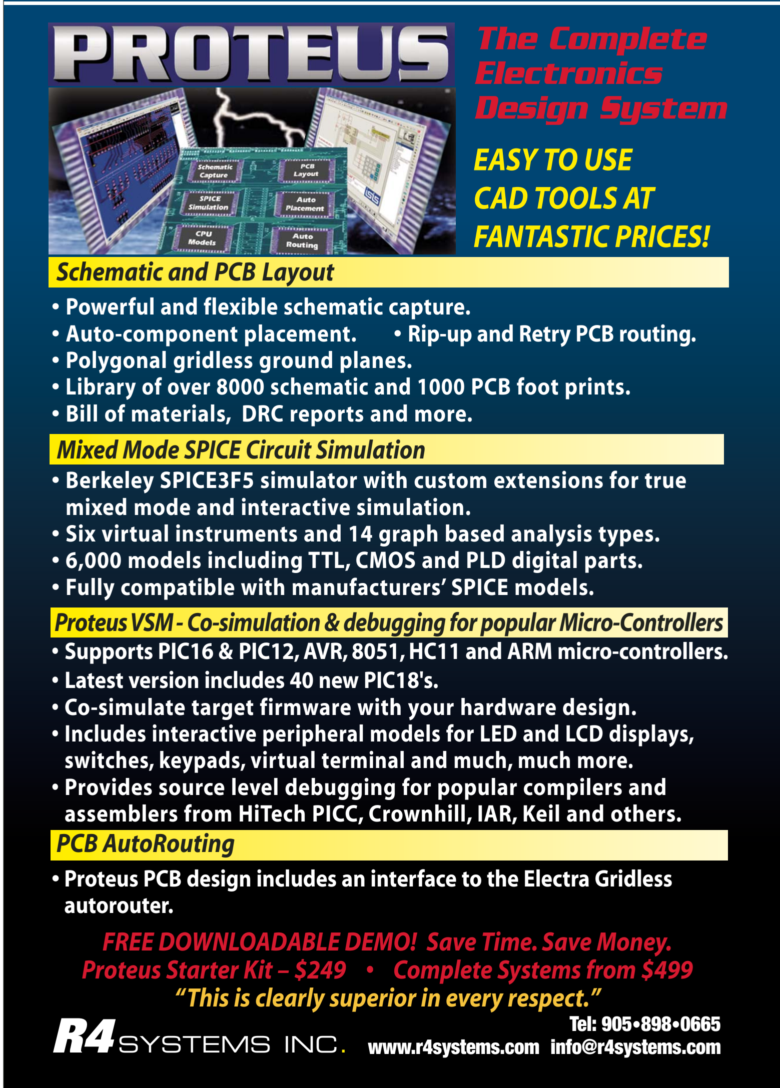
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SHOWCASE

The BRAIN-COMPUTER Interface

"IT'S NOT SCIENCE FICTION ANYMORE!"

by James L. Antonakos

Popular culture was recently taken for a wild ride in the three *Matrix* movies, where Neo and his band of survivors plugged their brains into the computer-controlled Matrix to battle evil and save the world. In *Minority Report,* three 'PreCogs' have their brains wired up to record crimes that occur in the future. Science fiction has long been fascinated with the idea of tapping into the human brain.

The photo above is a computer rendering of the Cerebus device done by one of its designers, Scott Eaton.

Date	Milestone
1808	Franz Gall publishes work on Phrenology — a now discredited science for measuring brain capacities.
1848	Phineas Gage has an iron rod blown into his brain during an accident, and lives, with profound personality changes.
1891	Wilhelm von Waldeyer coins the term *neuron*.
1936	First lobotomy performed in the US.
1953	Rapid Eye Movements (REM) discovered.
1981	Roger Sperry awarded Nobel Prize in Physiology for his discoveries in the functional specialization of the cerebral hemispheres.
2004	FDA approves clinical trial of brain implant developed by Cyberkinetics, Inc.

TABLE 1. TIMELINE OF BRAIN RESEARCH MILESTONES.

Pattern Name	Frequency Range (Hz)	Activity Represented
Delta	1-4	Deep sleep
Theta	4-8	Normal sleep
Alpha	8-13	Awake
Beta	13-30	Possibly medicated

TABLE 2. CLASSIFICATION OF EEG PATTERNS.

In 1972, Michael Crichton's *The Terminal Man* explored the use of a brain implant to treat a patient suffering from blackouts. The 1991 Star Trek: The Next Generation episode *The Nth Degree* had a crew member construct a holographic interface to connect his brain to the ship's computer.

Brain interfacing technology has gone from science fiction to the real world. Already there are many companies offering hardware and software products for making the brain connection. Educational institutions are performing research, medical researchers are devising ways to assist the differently-abled, and security professionals are using brain fingerprinting techniques to help assess an individual's state of mind.

Searching on Yahoo! for the words *brain computer interface* yields over 770,000 web pages. Clearly, there is a good deal of interest in this subject and its related offshoots. A brief history of milestones in brain research are listed in Table 1.

The purpose of a brain-computer interface is to tap into the electrical signals that are generated by the brain. Where do those signals come from? There are hundreds of billions of cells in the human brain, called neurons, with a myriad number of interconnections with each other. The neurons communicate using electrochemicals called neurotransmitters. Groups of neurons fire together to control some action in the body (or guide some other brain process).

The use of charged ions in the chemical reactions accounts for the electrical activity that can be measured and acted upon. The waveforms generated by the brain (called brainwaves) are classified into several different categories, depending on what the brain is doing. Each category has its own frequency range and characteristics. Table 2 lists the brainwave categories, which are also called EEG waveforms or EEG patterns.

There are essentially two camps in the BCI world: those that utilize invasive brain technology and those that use non-invasive technology. The goal of both technologies is to sense brainwaves. An invasive brain sensor consists of one or more electrodes surgically inserted under the scalp or directly into the brain. Figure 1 shows one type of invasive sensor, a two-dimensional array measuring two millimeters on each side, containing 100 miniature electrodes.

Note that brain implants are used for long-term monitoring. A non-invasive sensor is simply placed onto the scalp (using an appropriate

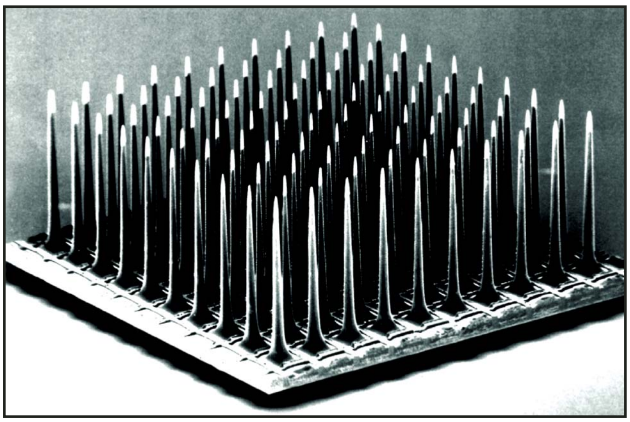

FIGURE 1. INVASIVE BRAIN IMPLANT. IMAGE COURTESY OF CYBERKINETICS, INC.

Terms

Brain Fingerprinting
A technique to measure brain response to crime-relevant stimulus.

Closed-Loop System
A system that uses feedback to send a portion of the output signal back to the input. The output influences what the next output will be.

EEG
Electroencephalogram — patterns of electrical brain activity that can be sensed on the scalp. Also called brainwaves.

EEG Biofeedback
Process where an individual trains their brain by watching their own EEG brainwaves. Also called brainwave training.

Galvanic Skin Response (GSR)
Changes in the electrical properties of the skin due to anxiety or stress.

Invasive Brain Procedure
A brain sensor is medically inserted into the body.

MERMER
Memory and Encoding-Related Multifaceted Electroencephalographic Response — a wavelike response generated by the brain during recognition.

Neuron
One of billions of brain cells that uses electrochemical signals for communication.

Non-Invasive Brain Procedure
A brain sensor is attached externally.

P300 Complex
A group of well-known brainwave components that can be measured.

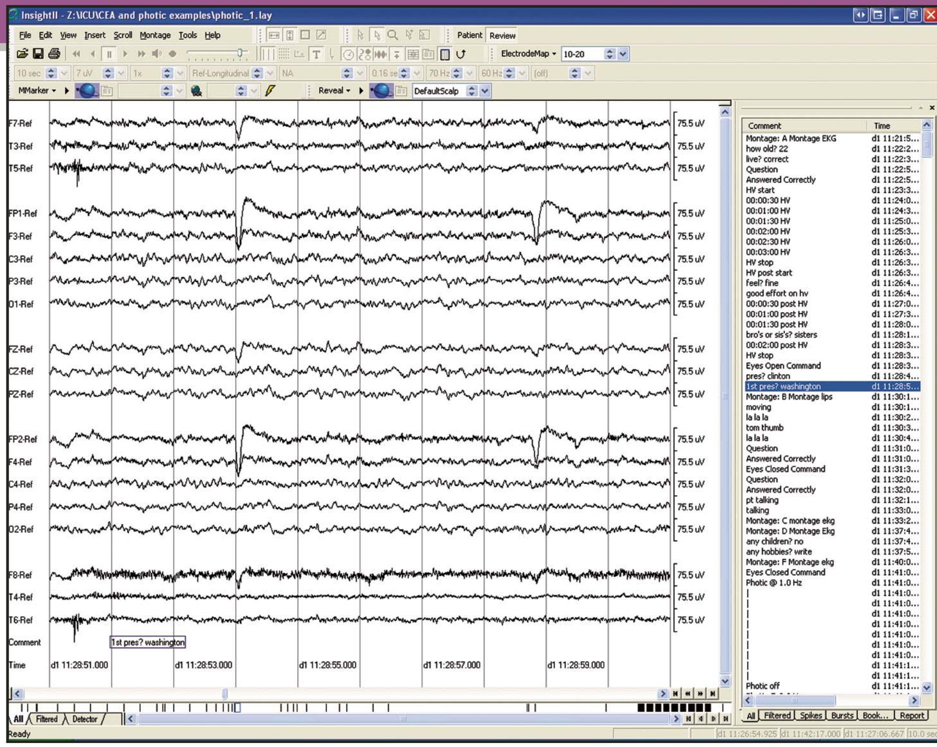

FIGURE 2. EEG BRAINWAVE ACTIVITY OF A 22-YEAR OLD SUBJECT DURING A SHORT QUESTION-ANSWER PERIOD. THE DISPLAYED ACTIVITY SPANS 10 SECONDS. IMAGE COURTESY OF PERSYST DEVELOPMENT CORPORATION.

conductive gel). For long-term monitoring with this type of sensor, the conductive gel contains an adhesive. Both types of sensors transmit electrical activity to a computer or monitoring/recording device, where it is digitized and analyzed. This leads to an interesting question: How fast should brainwave information be gathered? The answer depends on the frequency characteristics of brainwaves, which change according to our activities.

One BCI system samples the brainwave signal at a rate of 128 Hz. Using sampling theory, this sample rate guarantees accurate sampling of frequencies up to 64 Hz. Another system samples at 240 Hz, giving a 120 Hz maximum signal rate. Compare these frequency sampling limits with the various EEG patterns listed in Table 2.

From the frequencies shown in Table 2, we realize it does not require a Flash A/D converter to accurately sample an EEG waveform. Furthermore, with such a low-frequency information signal, the computer is able to perform real-time analysis of the waveform, look for trends in amplitude change or other rhythms, and adjust the overall system accordingly.

The Insight II software from Persyst Development Corporation is one application that allows EEG display and analysis of captured brainwave activity. As shown in Figure 2, multiple brainwaves can be displayed simultaneously, as they might have looked on an analog chart recorder.

Figure 2 illustrates an important property: the brain-computer interface is bi-directional! We do not just siphon data from the brain, but instead use the brain information to craft a feedback stimulus. In Figure 2, the stimulus is the question being asked and the feedback is the subject's response.

In another example, suppose a patient is trying to train her brain to move the cursor left, and it moves right instead. The patient needs to know that. Typically, the patient's sight would tell her if the cursor is moving in the correct direction. But what if she was blind, or visually impaired enough to not see the cursor move? Some other kind of feedback will need to be used (such as an audio indication).

We may even send signals back into the brain to stimulate it. Since the mid-1800s, brain researchers have known which portions of the brain are responsible for movement. By implanting an electrode in the area that controls muscles in the legs, for example, the leg is caused to move by application of an electrical stimulus to the brain.

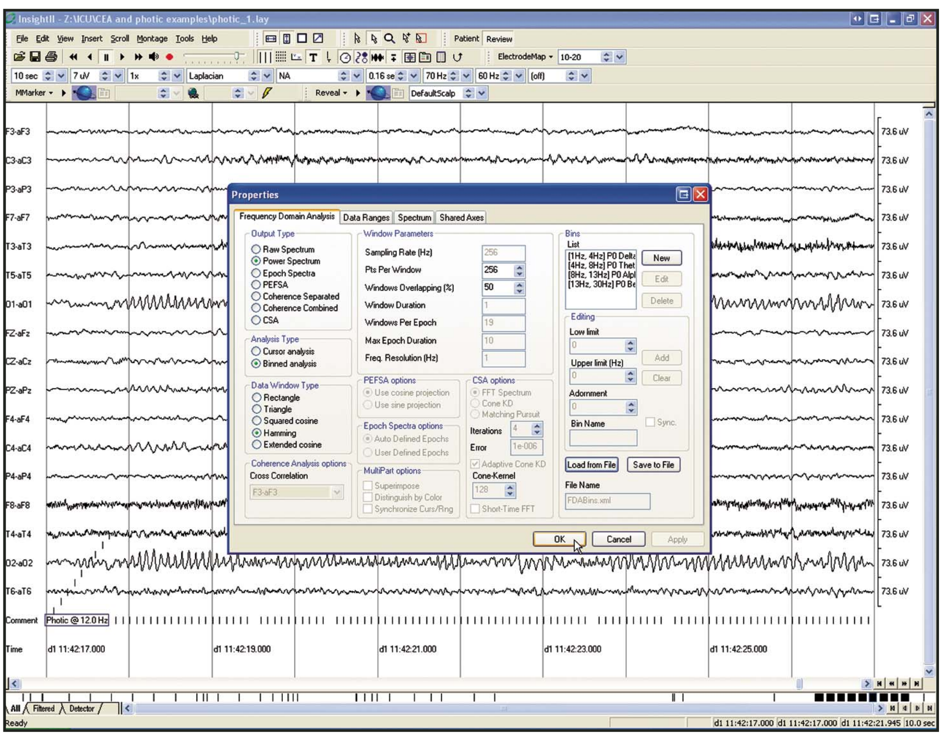

FIGURE 3. ANALYSIS OF EEG RESPONSE. NOTE THE WIDE NUMBER OF OPTIONS FOR FREQUENCY ANALYSIS. IMAGE COURTESY OF PERSYST DEVELOPMENT CORP.

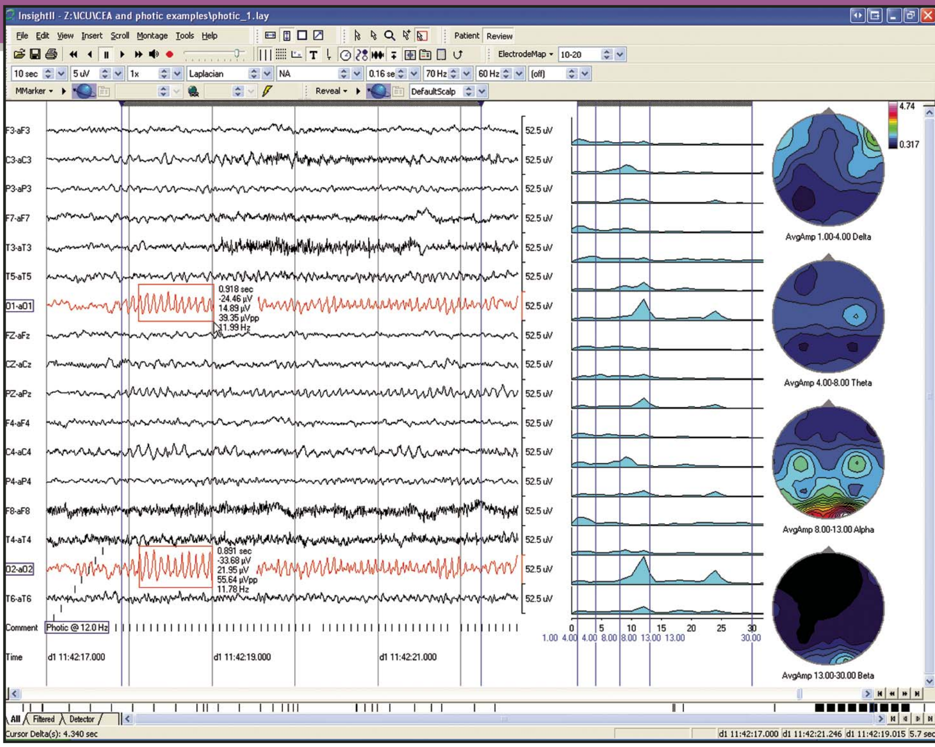

FIGURE 4. GRAPHICAL DISPLAY OF FREQUENCY PATTERNS WITHIN THE BRAIN IN RESPONSE TO A STROBE LIGHT STIMULUS. AT RIGHT IN THE ANALYSIS WINDOW ARE FOUR VIEWS OF THE FREQUENCY PATTERNS LOOKING DOWN INTO THE BRAIN FROM THE TOP OF THE HEAD, WITH THE EYES POINTING NORTH. IMAGE COURTESY OF PERSYST DEVELOPMENT CORPORATION.

Research into the medical aspects of the brain-computer interface is wide ranging and popular. The web is filled with research papers with titles such as:

- *Improving Transfer Rates in Brain Computer Interfacing*
- *The Berlin Brain-Computer Interface (BBCI): Towards a New Communication Channel for Online Control of Multimedia Applications and Computer Games*
- *On the Possibility of Developing a Brain-Computer Interface (BCI)*
- *The use of the P3 Evoked Potential Component for Control in a Virtual Apartment*
- *Brain-Computer Interface in Multimedia Communication*

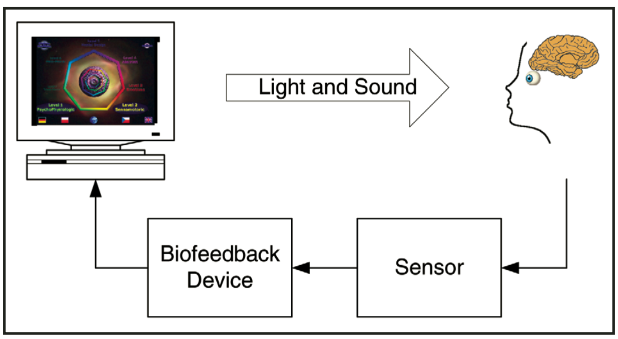

FIGURE 5. CLOSED-LOOP FEEDBACK SYSTEM WITH A HUMAN IN THE LOOP.

Some of this research is directed into the security aspects of brain activity. For example, it is well established that, upon seeing a familiar scene or hearing a familiar sound, the brain emits a wavelike response called the P300 Complex (part of the larger MERMER response) 300 to 800 milliseconds after the brain has been stimulated. This response has already been used in a court of law to establish that the wrong person may be locked up for a crime, since his brain response indicates no recognition of the crime scene. This new science is called Brain Fingerprinting. You can expect it to be as controversial as DNA evidence once it becomes standard practice.

Want to start experimenting with your own brain? For as little as $20, you can start with a simple combination strobe light/sound machine. A more advanced device — the Proteus Sound and Light Machine — generates pulsing colors and stereo sound, and contains a biofeedback interface.

There are plenty of personal biofeedback devices on the market (referred to as mind machines). These devices typically measure Galvanic Skin Response (GSR) — changes in the skin's resistance due to biological factors caused by stress and anxiety.

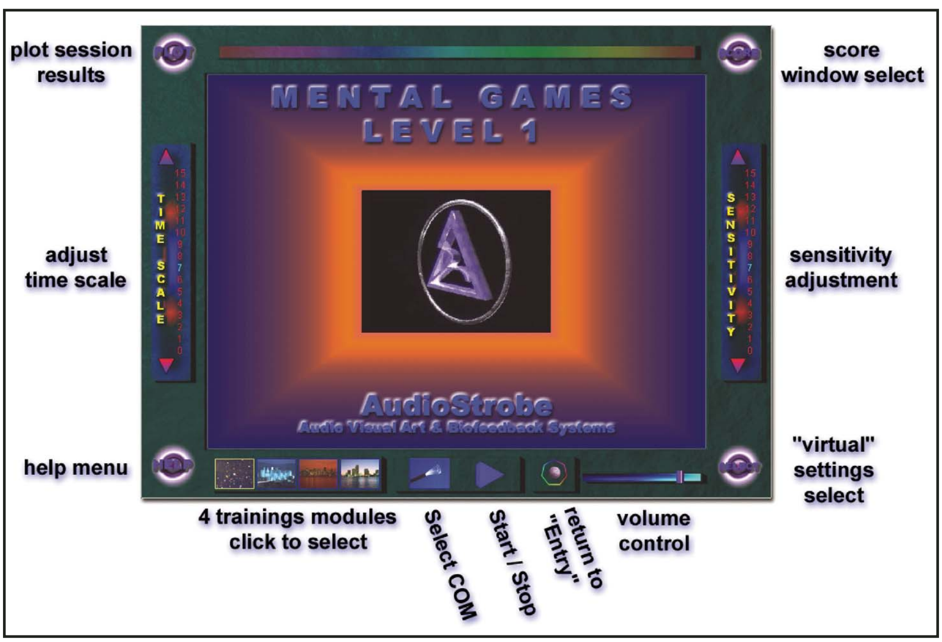

FIGURE 6. MENTAL GAMES SOFTWARE. SCREENSHOT COURTESY OF IPRODUCTS.WS

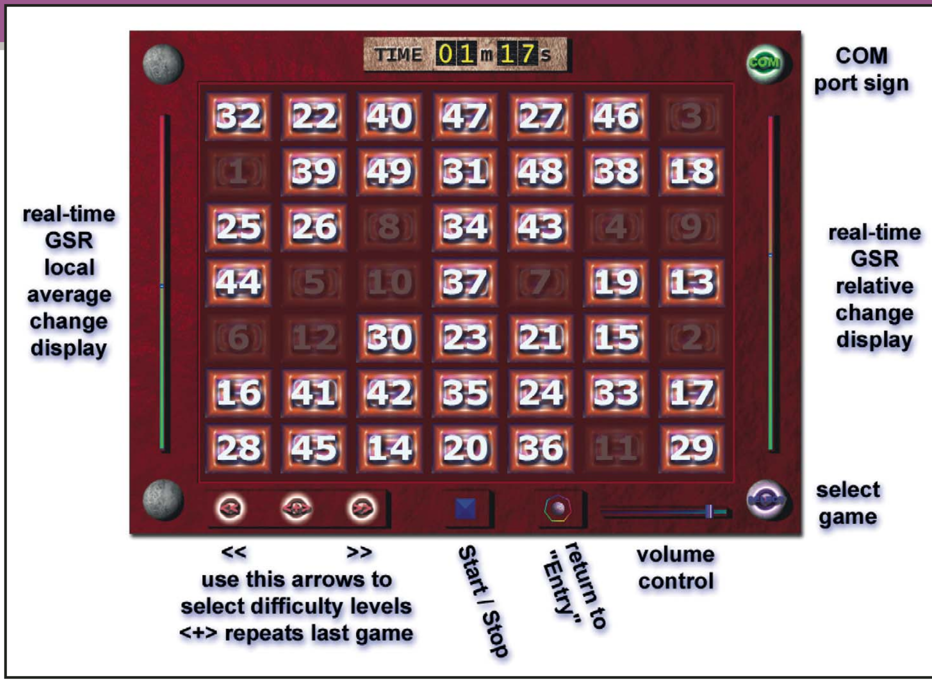

FIGURE 7. MENTAL GAMES SOFTWARE. SCREENSHOT COURTESY OF IPRODUCTS.WS

The sensors attach to the palms or fingertips of the user's hands. For $100 to $200, you can choose from a large variety of quality products.

The ThoughtStream Biofeedback System is one such product, providing audio and visual feedback in response to GSR changes in the user. To enhance the training experience, the Thought Stream allows the user to create a closed-loop feedback system using the ThoughtStream and a PC, and special software called Mental Games.

The ThoughtStream machine connects to the PC via a serial cable. As the user watches the images produced by the Mental Games software, changes in GSR are measured by the ThoughtStream machine, fed to the PC through the serial cable, and interpreted by the software. This forms a closed-loop system, with the brain-body inserted directly into the loop, as indicated in Figure 5.

The ThoughtStream's Mental Games software is psychointeractive software designed to assist you in training your mind. The games involve landing and navigating spaceships in virtual environments and other time and space related activities, as shown in Figures 6 and 7.

Unless your situation is one of medical necessity, it is unlikely you will be able to have a sensor installed directly into your brain (unless the brain interface goes the way of the cell phone and comes with bonuses, such as fingerprint forwarding and stimulus waiting). However, if you are disabled or differently-abled, the hardware and software tools are already out there to help you begin getting back some control. The capabilities go far beyond two-dimensional cursor control. For example, the CyberLink System (from www.brainfingers.com) has a software development kit that allows the patient to develop new C++ or Visual Basic applications.

Skip ahead to a future time when electronic instruments are so sensi-

Acknowledgments

I would like to thank Michael Guess of Persyst Development Corporation for his illuminating discussions of the brain and its behavior and his screenshots of the Insight II software.

I would also like to thank James Quick of iProducts.ws for his images of the ThoughtStream Biofeedback System Mental Games software.

References, Vendors, and Further Exploration

Patients Put on Thinking Caps, Wired News
www.wired.com/news/medtech/0,1286,66259,00.html?tw=wn_story_top5
Good story on how physical handicaps may be overcome through a brain-computer interface.

Cyberkinetics Neurotechnology Systems, Inc.
www.cyberkineticsinc.com
Developers of the BrainGate™ System which utilizes an implanted device to stimulate or record from the brain surface.

Neural Signals, Inc.
www.neuralsignals.com
Developers of the Neurotrophic Electrode, which implants into the brain. Software interface allows patient to control the computer's mouse, enter text, browse the Internet, and control environmental conditions.

Wadsworth Center
www.wadsworth.org/resnres/wolpaw.htm
Brain-computer interface research based on non-invasive EEG recording and analysis.

PBS Website on the Brain
www.pbs.org/wgbh/aso/tryit/brain
Interactive Shockwave demo allows you to explore the motor cortex of the brain.

The Brain, V2.0
www.vankuyen.net/brain
Good reference on the brain and its components.

How the Brain Works
http://keck.ucsf.edu/~paul/brain.html
Excellent description of brain activity.

EEG Spectrum International
www.eegspectrum.com
Biofeedback training for medical purposes.

Persyst Development Corporation
www.eegpersyst.com/web/MagicMarker.html
Developers of MagicMarker ICU and Neonatal EEG monitoring software and Insight II EEG Analysis software.

IProducts.ws Cutting Edge Merchandise
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Distributors of the ThoughtStream Biofeedback System and other Mind Machines.

tive they can read your brainwaves from a distance. Perhaps these sensors could be installed in the very walls of our homes, in the dashboards of our cars, or in drinking fountains.

No more Social Security number, just a digitized brainwave signature unique to your brain. No more credit card at the checkout counter, just a wave of a wand over your head. There is opportunity for abuse, there are social implications, and, for some, the very essence of a meaningful life, all wrapped up in the expanding brain-computer connection. **NV**

About the Author

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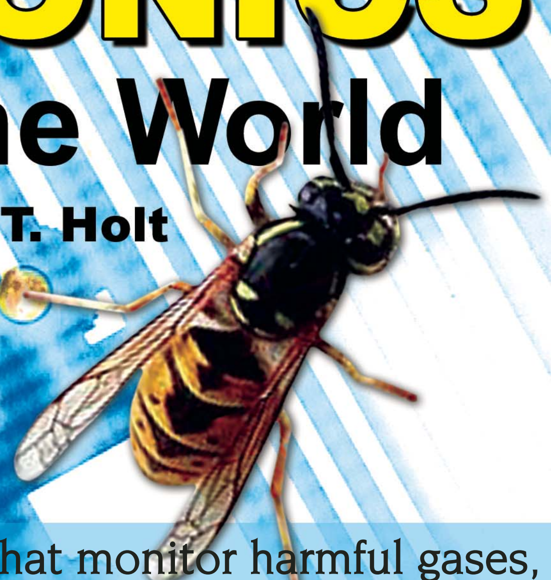
Fusion of BIOLOGICAL ORGANISMS and ELECTRONICS May Save the World

by Christopher T. Holt



As a designer of chemical sensors that monitor harmful gases, I have always been intrigued by nature's ability to detect chemicals at one-molecule-per-trillion concentration levels. Current chemical and biological detection technology still pales in comparison to the reliable sensory system of a properly trained biological organism in terms of sensitivity and selectivity to the molecule of interest.

Canine units are invaluable to law enforcement agencies when used to detect various types of contraband. They have also proven their worth in the area of humanitarian de-mining efforts. Amazingly, a mine-detection dog is capable of detecting the explosive chemicals that diffuse through the mine casing. However, the use of mine-detection dogs is cost prohibitive for the third-world countries that most need this technology.

The use of whole organisms as chemical sensors is not a new idea or novel concept. I wonder how many coal miners managed to skip purchasing their halo early because of some unlucky canary in a cage. However, the integration of organisms like rodents or insects with off-the-shelf electronics is a fairly new area of R&D. Scientists and engineers have long recognized nature's superiority in olfactory design, and the US government, specifically the Defense Advanced Research Projects Agency (DARPA), under the Controlled Biological Systems Program, has invested millions of dollars in this area of research.

Researchers at the University of Georgia and USDA Crop Management and Research Laboratory, with funding from DARPA, have trained a type

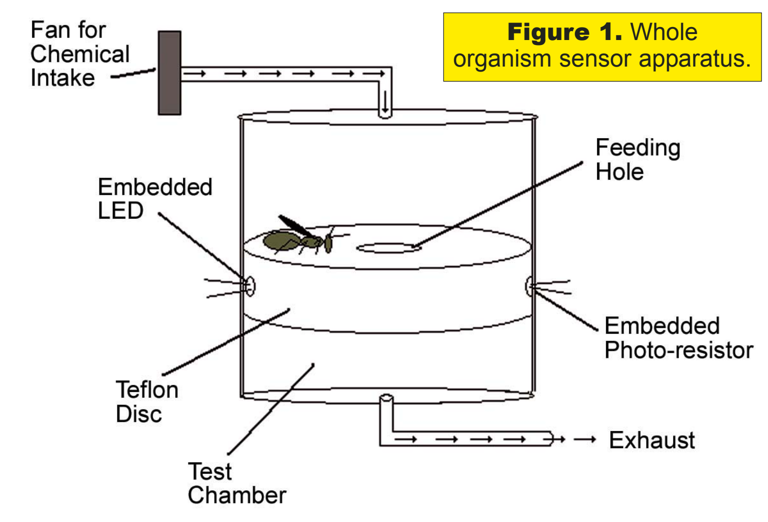


Figure 1. Whole organism sensor apparatus.

References

[1] D.M. Oson, et al., "Parasitic Wasps Learn to Report Diverse Chemicals with Unique Conditionable Behaviors," *Chemical Senses*, 28: 545-549, 2003.

[2] G.C. Rains, G.C., et al., "Development of a programmable whole-organism wasp sensor for monitoring crop conditions from volatile chemicals," ASAE Paper No. 003062 St. Josephs, MI, *ASAE*, 2000.

[3] www.tifton.uga.edu/grains/main.html

[4] http://beekeeper.dbs.umt.edu/~bees/science.html

[5] J. Otto, et al., "Training Rats to Search for Contraband Odors," *Applied Animal Behaviour Science*, 77: 217-232 (2002).

of parasitic wasp species, *Microplitis croceipes,* to detect various chemicals including DNT, a common chemical found in explosives [1-3]. This particular wasp species owes its very existence to its ability to detect chemical cues in the environment in order to increase foraging success.

The key to developing a whole-organism sensor lies in the old psychological methods of classical conditioning or associative learning. Remember Pavlov's salivating dogs from Psychology 101? Well, apparently this concept of associative learning works just as well for wasps. During training, the wasps were presented with the chemical of interest while feeding on sugar water from a small hole drilled in a Teflon plate. After doing this a few times, the wasp learns to associate the chemical with feeding on sugar water. After it's been conditioned in this way, the wasp will go down a hole to feed whenever it senses that chemical. Then, all you have to do is add a light-emitting diode and photo resistor in the hole to detect the presence of the conditioned wasp and you have a low-cost biological detector. (See Figures 1 and 2.)

The setup in Figure 1 and the electronic comparator circuit in Figure 2 could easily be used for a science project or for your own independent research in invertebrate chemical communication. The comparator circuit can be adjusted using the variable resistance to set the voltage reference. When the LED is blocked by a wasp exhibiting feeding behavior (chemical detected), the voltage at the non-inverting input is higher than the reference voltage at the inverting input, and the alarm (piezo-buzzer) sounds. For you BASIC Stamp aficionados, the versatile RCTIME command could be applied to interface a photo-resistor-plus-capacitor combination instead of the op-amp-comparator-detector circuit shown in Figure 2.

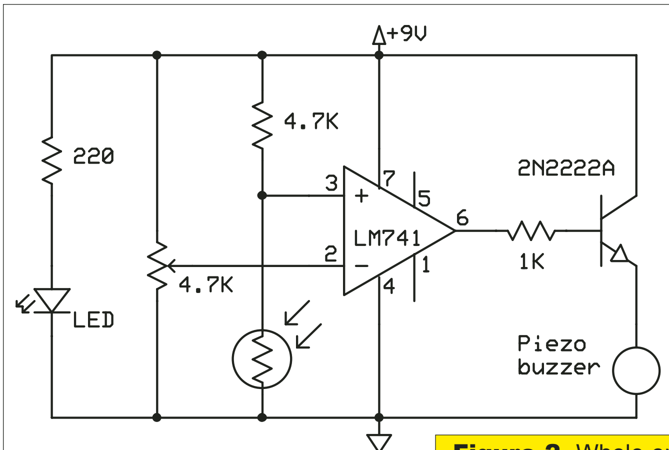
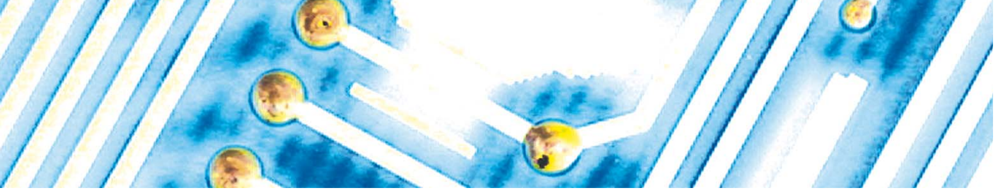


Figure 2. Whole organism detector circuit.

The most interesting part of the University of Georgia research is that the wasps appear to have some plasticity or flexibility in the range and number of chemicals they can detect. This suggests their use as programmable sensors that can be used to detect numerous odors. With the high reproduction rates of most insects, you have the added advantage of selecting for the best performing individuals and after a few generations, you have an almost fail-safe detector.

Entomologists at the University of Montana have computerized bee hives in an effort to collect environmental data [4]. The idea is to use the bees as environmental sentinels that go out and forage in the environment for pollen while inadvertently collecting whatever residual pollutants may reside there. After foraging, the bees return to the electronic hive, where standard chemical sampling systems are used to detect the various pollutants they have carried back with them. This electronic hive system could potentially provide real-time information on environmental quality, help with ecological risk assessment, and be used to detect biowarfare agents.

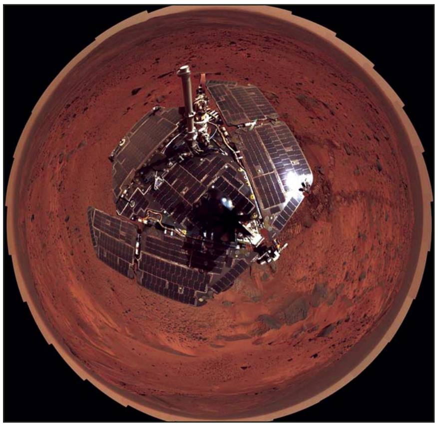
Researchers have even gone as far as recruiting rats to do the work of Fido in the detection of illegal drugs. It makes sense considering that they are cheaper, smaller (which can be an advantage when searching in tight spaces), and require fewer resources throughout their life cycle than dogs. Research at Villanova University and the University of Baltimore has shown



the feasibility of using rats to detect contraband [5]. The rats were taught to rear on their hind legs upon identification of contraband odors. During the research, the rats were outfitted with a miniature harness with motion sensors that signaled to a computer upon positive identification of contraband.

Now, I can deal with a Beagle or German Shepard sniffing my luggage, but a rat with a backpack? I can't help but smile when I think of a possible future with mobile computerized organisms doing our bidding, acting as our eyes and ears (and noses) at the frontlines of a brave new world. **NV**

OH, AND YOUR JOB IS ON MARS



A bird's-eye view self-portrait of NASA's Mars Exploration Rover Spirit. (Photography courtesy of NASA/JPL-Caltech/Cornell)

On March 17, 2006, **NASA** named **John Callas** as the project manager for NASA's Mars Exploration Rover missions. Callas is a scientist at NASA's Jet Propulsion Laboratory (JPL) in Pasadena, CA.

"It continues to be an exciting adventure with each day like a whole new mission," Callas said.

That modesty is the epitome of understatement. For example, one of **Spirit's** six wheels has stopped working. Dragging that wheel, Spirit must sprint to a slope where it can catch enough rays to continue operating during the upcoming Martian winter. This period of minimum sunshine is more than 100 days away, but Spirit gets only enough power for about one hour per day of driving on flat ground.

And you think that your local robot competition is tough?

The best spot for Spirit's "snow bird" migration is the north-facing side of McCool Hill, where it could spend the southern-hemisphere winter tilted toward the sun just soakin' in the fun.

Spirit is currently driving toward the hill. It has approximately 120 meters (about 390 feet) to go. Expected progress is approximately 12 meters (40 feet) per day.

Jeez, if only we could get someone up there to push that thing, that would be great. Any volunteers?

ONE OF THE SELECT NXT FEW

LEGO Mindstorms NXT AlphaRex. (Photograph courtesy of © 2005 The LEGO Group)

The LEGO Group has officially released background information about the selection process for its new **Mindstorms® Developer Program** (MDP). First of all, if you weren't selected, don't feel slighted.

According to LEGO, the MDP is an exclusive cadre of 100 enthusiasts who are now charged with "helping guide the product development process for **LEGO® Mindstorms® NXT**, the next generation of LEGO robotics."

A total of 9,610 robotics enthusiasts, ages 18 to 75 years of age and representing 79 countries responded to the one-month online application process that was sponsored by LEGO. A thumbnail view of the 100 selected candidates shows that:

- Range in age from 18-75 (50% under age 35)
- More than 20% work in the software/QA/DBA sector
- Nearly 20% are teachers or educators
- 13 are architects or engineers
- 40% are from the US

Contributing Editor to *SERVO Magazine*, **Dave Prochnow** is one of the chosen few elected to the MDP. And, no, Dave isn't the 75 year-old MDP member, either. You can expect to see and read a lot of insider information from Dave starting in the NXT, err, next issue of *SERVO Magazine*.

BUGS AWAY

Have you ever thought that you could talk to the animals? Maybe even control the flight paths of butterflies? Well, Dr. Dolittle, Uncle Sam wants you.

On March 9, 2006, the Defense Advanced Research Projects Agency (**DARPA**) website posted a presolicitation notice for requesting research proposals in the area of **Hybrid Insect Micro-Electro-Mechanical Systems** (MEMS).

So funny that it's scary, the notice states: "DARPA seeks innovative proposals to develop technology to create insect-cyborgs, possibly enabled by intimately integrating microsystems within insects, during their early stages of metamorphoses.

"Once these platforms are integrated, various microsystem payloads can be mounted on the platforms with the goal of controlling insect locomotion, sense local environment, and scavenge power."

So what did noted bug bot builder **Mark W. Tilden** say about this project? According to Tilden, "We tried this for years and found that given perfect digital control, an organism will still do as it damn well pleases."

Got a hankering to bug a bug, get cracking, the "original response date" for your proposal submission is June 05, 2006.

You can learn more about this opportunity from the DARPA website, just look for solicitation BAA06-22 at: **www.darpa.mil/baa/baa06-22.html**

SHAMEFUL DISPLAY OF ROBOT ABUSE

This just in from **iRobot Corporation** Chairman and co-

founder, **Helen Greiner**, **Phillip Torrone** was spotted in Texas recently dis-ing a **Roomba**. Along with fellow techno-lackey, **Limor Fried**, they did willingly and without regard for proper traffic right-of-way laws hack a Roomba floor vacuum robot into a pale representative of the central character in the video arcade game, *Frogger*.

While the Bluetooth interface on the Roomba does have merit (Hey, Phillip, fame awaits you; *SERVO Magazine* is still waiting for an article about this interface), the lame *Frogger* suit adds insult to the inevitable Roomba injury.

Refer to the CNET News website for all of the gory details: **news.com.com/2300-1041_3-6049976-1.html?tag=ne.gall.pg**

SPEAKING ABOUT MOWING

Friendly Robotics RL800 Robomower (Photograph courtesy of Friendly Robotics®)

Looking at a Roomba, wouldn't it be great if you could buy a robot that could mow your lawn as good as Roomba vacuums your floors?

Co-founded in 1995 by Udi Peless and Shai Abramson, **Friendly Robotics®** (formerly known as Friendly Machines) markets a line of grass cutting robots called **Robomower®**.

Probably the best known Robomower is the RL800. This model can be purchased directly from Earth's most popular dealer: Amazon.com. Priced at $1,195.99, the RL800 might not fit into every home-owner's budget.

If you're looking for a little more down-to-earth robotic lawn mower, watch for our upcoming article in *SERVO Magazine* about building your own robotic lawn service for less than $200.

KAMEN'S LATEST KAPER

You really gotta love a guy like Dean Kamen. Rather than sitting around on his laurels, Mr. Segway is always hard at work trying to improve our daily lives. In his latest venture, Kamen has reached deep into his toolbox for a couple of engineering marvels which he hopes will alleviate the worldwide shortage of clean drinking water and bring electricity to the world's poorest people.

Kamen's two latest inventions are a water purification system that he calls Slingshot and an electricity-

generating Stirling engine that produces one kilowatt of electricity from cow manure.

But Kamen doesn't want to fly solo on this venture. He's enlisting entrepreneurs like the founder of a Bangladesh cell phone company, Iqbal Quadir, to help with the business model.

Quadir's model follows a similar one that he developed for his cell phone company. How do you bring cell phone technology to villagers who are too poor to own a phone? Quadir used a "micro-credit" program where one person designated the "village entrepreneur" is given a loan for the cell phones and service.

This village entrepreneur then sells the service on a "per call" basis to any villager who needs to reach out and touch someone.

Does this micro-credit approach work? According to Quadir, there are over 200,000 village entrepreneurs participating in his cell phone business model. Now he wants to do the same with electricity and that's where Dean Kamen comes in.

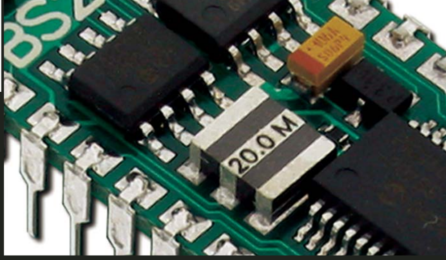
Together the entrepreneur and the engineer have formed a company called Emergence Energy. Supported with funding from The Lemelson Foundation, Emergence Energy is evaluating this same micro-credit model as a means for bringing energy production to villagers in Bangladesh.

Based on Kamen's own brilliant Stirling engine design, these micro-power plants will utilize three village entrepreneurs instead of the single one used in the cell phone business model. In this model, one villager acquires the fuel (cow poop), another sells the electricity, while the third one sells light bulbs. Ya gotta love being the ""cow dung" entrepreneur.

While not exactly integrated with the electricity production model, Kamen's water purification system could work in concert with the Stirling engine. Slingshot works by vaporizing water from sewage and separates the clean water from the leftover waste. This waste could then be used, in turn, to fuel the Stirling engine.

All of this benevolence doesn't come cheap, however. The test Stirling engines cost $100,000 to build. The goal of Emergence Energy is to lower that price into the $1,000 to $2,000 ballpark. Once this price point can be achieved, Quadir believes that he can market 500,000 power plants in Bangladesh, alone.

Let there be light. **NV**



STAMP APPLICATIONS

PUTTING THE SPOTLIGHT ON BASIC STAMP PROJECTS, HINTS & TIPS

■ BY JON WILLIAMS

THE OBJECT OF THE MACHINE

SO, IS YOUR HEAD SPINNING after last month's introduction to the Propeller chip? Don't worry, it happens to all of us, and I promise that after a bit of time things will begin to click, a big smile will cross your face, and wonderful things you thought never possible will start happening. Last month we talked about the Spin programming language being object oriented, but didn't really take advantage of it. Let's change that, shall we? and unleash some of the power of the Propeller multi-controller.

While I consider myself a pretty fair programmer, I always qualify that statement with the assertion that I'm a pretty fair *high-level language* programmer. Of course, I can program a bit of assembly, but I really don't like to. What that means, then, is when I've wanted to incorporate assembly code written by another programmer (e.g., in an SX/B project), it's been a bit of work. I've got great news for Propeller users: using assembly language written by another programmer is no trouble at all, and we're going to see that this month.

But let's go through a bit of a review first. Remember that the Propeller chip has eight 32-bit cogs (processors) in it, and all can be running at the same time. Every cog that is running has direct access to the I/O pins, as well as to the main system counter (useful for generating delays). There is a system manager called the "hub" that controls access to the shared resources; specifically the main system RAM (32 KB).

A cog can run the Spin language interpreter or a custom assembly language program. The fact is that the Spin interpreter is an assembly language program that is loaded from the system ROM when needed. So, for those of you concerned about each cog having only 2 KB of RAM, don't be; this is plenty for assembly programs (remember, this is a whole new assembly language and is very efficient). Any Spin code that we write actually resides in the main system RAM, so our Spin programs and their data space can be up to 32 KB. Of course, there is a performance difference between Spin and Assembly, by about a factor of 250x. That said, Chip (that clever guy who created the BASIC Stamp) has estimated that with a 5 MHz crystal and using the 16x PLL tap (system clock of 80 MHz), we can run about 80,000 Spin instructions per second. That's pretty fast.

So let's jump right in and demonstrate Propeller objects and the ability to use assembly language with our Spin projects. For our first project we're going to create a "debug" object that allows us to send information to a PC. Some of you may be surprised that this is not a built-in function — don't be. The Propeller is a different beast and you wouldn't want to be penalized by having code space consumed by unused functions. Let's say you'd rather send values to a TV; you can do that using the *TV_Terminal* object that Chip wrote and comes with the Propeller installation. In fact, I've borrowed the numeric conversion routines from *TV_Terminal* object for us in *PC_Debug*. Let's build that object.

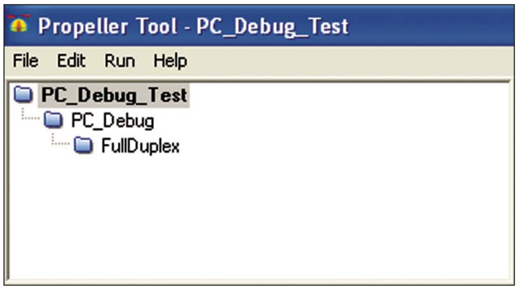
The purpose of *PC_Debug* is, of course, to send information to a PC terminal program. What this means, then, is that we need a code to handle the serial transmission. While we could do that ourselves, why bother? Chip has kindly written a high-performance UART object called *FullDuplex* that we can take advantage of. What we're going to do with *PC_Debug* is provide a convenient wrapper for *FullDuplex* that gives us access to most of the methods in *FullDuplex*, as well as adding any conveniences that we might like to have (like number-to-string conversion).

Notice that the ZIP file I've provided for downloading this month (available on the *Nuts & Volts* website; **www.nutsvolts.com**) has a very specific name and naming convention; this is actually a Propeller archive file. We'll talk more about archives later; just know for the moment that an archive contains all the files we need for a given project. Expand the archive so that you can open the files with the Propeller Tool, and then have a look at *PC_Debug.spin*.

In order to use an object in our program we need to declare it; we do that in the **OBJ** block like this:

```
OBJ
  uart : "fullduplex"
```

We now have an object in our project called "uart" that — once started — gives us buffered serial communications using another cog (which means it can do things without affecting the program running in the main program cog). What we've done, in essence, is added a serial coprocessor to our system. Pretty cool, huh? It gets better.



■ FIGURE 1. Object Hierarchy.

The Parallax philosophy is that support objects, i.e., those that are not intended to stand alone, will have a method called "*start*" that is used for instantiation. The *start* method will usually return True (-1) or False (0) based on the success of the code at *start*. Note that there is no hard-and-fast rule on this, it's just the current convention.

Since *PC_Debug* is also designed as a support object, it will also have a *start* method. Here it is:

```
PUB start(baud) : okay

  okay := uart.start(31, 30, baud)
```

This is a simple method, and yet a lot is happening. We start with the **PUB** declaration — we need this method to be public so that it can be accessed by higher-level objects. This method is expecting a parameter called *baud*. Note that no matter what size we need, a parameter is always passed as a Long. This method will return a value as well; the variable after the colon (*okay*) is what will be returned. Return values are also Longs but can be caste to smaller sizes (Word or Byte) if needed.

The code now is just one line: we're assigning the return value of the *uart.start* method to *okay*. As we can see, Spin uses the dot notation found in other object-oriented languages. We can also tell that the *uart.start* method expects three parameters: the receive pin, the transmit pin, and the baud rate. What we've done here is started the *uart* object using the Propeller's standard programming pins.

But what if we've got an extra port on our PC and would rather send information to it using a couple free I/O pins? No problem, we'll just create another method.

```
PUB startx(rx_pin, tx_pin, baud) : okay

  okay := uart.start(rx_pin, tx_pin, baud)
```

As you can see the *startx* (x for extra) method simply passes along the desired pins with the baud rate. Using this method we could actually open more than one terminal at the same time (using different ports on our PC, of course). Spin even lets us define an array of objects, so we could do this:

```
OBJ
  terminal[2] : "pc_debug"
```

Now we just need to assign the terminals to different Propeller I/O pins.

```
PUB main

  terminal[0].start(9600)
  terminal[1].startx(1, 0, 57600)
```

In this case *terminal.[0]* is using the default programming pins (A31 and A30) at 9600 baud, and *terminal.[1]* is using A1 (for RX) and A0 (for TX) at 57,600 baud. Keep in mind that underneath the terminal object is the *FullDuplex* UART object that requires its own cog, so the definition above would require two free cogs to operate.

Let's get back to our *PC_Debug* object. Again, this is a wrapper for *FullDuplex* that adds features convenient for sending data to a terminal. Since the *FullDuplex* object starts a new cog, it also has a method for stopping that cog and making it available for other processes. By convention, this method is called *stop* and we simply provide access to it.

```
PUB stop

  uart.stop
```

This may seem redundant but, in fact, it's not. You see, any program (top object) that uses *PC_Debug* will not direct access to methods in *FullDuplex* — we must explicitly provide wrappers for them. The good thing about this is that we can provide wrappers only as needed and leave the other methods (even public ones) protected to a degree. Figure 1 shows the object hierarchy of our completed project. Note that *PC_Debug_Test* does not have a direct connection to *Full_Duplex*.

As you look through the *PC_Debug* object, you'll see that that are several other wrappers for objects in *FullDuplex*. They're self-evident and we don't need to describe them all in detail.

Let's jump into the custom methods that are at the purpose of our project: converting values to strings so that we can send them to a terminal program. Since we'll most frequently use decimal values, let's start there. The following method will print a signed decimal number:

```
PUB dec(value) | div, zpad

  if (value < 0)
    -value
    out("-")

  div := 1_000_000_000
  zpad~

  repeat 10
    if (value => div)
      out(value / div + "0")
      value //= div
      zpad~~
    elseif zpad or (div == 1)
      out("0")
    div /= 10
```

Okay, I know that this may look a little cryptic at first, but please trust me that once you get used to Spin you'll love the efficiency of the language. As I told you last month, Spin borrows from other languages, and those of you that have programmed in C will probably recognize some of the operators and constructs right away.

Let's start with the declaration because it includes something new. We can see that we're going to pass a value, and following that is a vertical bar and two symbols: *div* and *zpad*. The symbols are local variables that will be used by the method. Note that local variables are not persistent and will be destroyed when we exit from the method.

The beginning of the code is quite simple; we simply check to see if the value passed is negative and if it is we make it positive and print a "-" character with the *out* method. Next we initialize the divisor (*div*) and clear the *zpad* flag. There are a few cool things here: with 32 bits, we can deal with *really big* numbers (-2,147,483,648 to +2,147,483,647) and Spin lets us see this clearly by using an underscore character where a comma would normally be. Next is a new operator, the post clear (~) operator.

As you spend more time, you'll find Spin is very advanced, and the placement of an operator can change its meaning considerably. In our case, the trailing tilde means that we're going to clear the variable to zero. So ...

```
zpad~
```

is the same as

```
zpad := 0
```

but the former version is, in fact, more efficient internally. Now we get to the meat of the *dec* method. Since the largest value in the system can be up to 10 digits wide, we'll run the digit conversion loop 10 times. Again, note the efficiency with the simple **repeat 10** statement; this replaces **for x = 1 to 10** in Basic (though there is an implementation of **repeat** that allows us to specify start and end values). You may be wondering about the control variable for the **repeat** loop; this comes from the interpreter's stack.

Now we check to see if *value* is equal to or greater than the divisor. If it is, we get the current column digit by dividing *value* by the divisor, and then convert it to ASCII by adding "0" (decimal 48). Now we remove the current column by taking the modulus of the divisor. Since we've started printing digits, we will now set the *zpad* flag so that we print zeros in proceeding columns as needed. Note the post-set operator (two trailing tildes); this sets all the bits of the variable to 1 (making the value -1, which is generally used as True).

When the current value is less than the divisor, we check the *zpad* flag or for the current column being 1; if either of those conditions is true then we'll print a zero. The final step is to adjust the divisor between columns by dividing it by 10.

Okay, now let's look at binary and hex conversion. These routines are trim and elegant (*I didn't create them so I can say that*), yet also demonstrate some neat features in Spin. We'll start with binary as it is the simpler of the two.

```
PUB bin(value, digits)

  digits := 1 #> digits <# 32
  value <<= 32 - digits
  repeat digits
    out((value <-= 1) & %1 + "0")
```

This method differs slightly from *dec* in that we're required to specify a number of digits, but as you can see, there's really not much to the code. We start by qualifying the *digits* parameter with the **#>** (limit minimum) and **<#** (limit maximum) operators. This takes care of a bad value getting passed to the method. Then we shift the MSB of the printed output to bit 31 with the left shift operator. Note that as with many other operators, left-shift (**<<**) and variable assignment (**:=**) are combined into a single operator.

Now for the real work: a loop is used to print the number of digits passed. The code starts by rotating the bits left one position. Rotating differs from shifting in that no bits are lost, they simply wrap around to the other end of the value. So when we rotate left (**<-**) by one bit, what was in bit 31 ends up in bit 0. Now we AND this with %1, and then convert the digit to ASCII for printing. I don't know about you, but I think this routine is pretty darned nifty.

Okay ... ready for hex conversion? It's similar, but we're dealing with nibbles so there's a little extra in the code.

```
PUB hex(value, digits)

  digits := 1 #> digits <# 8
  value <<= (8 - digits) << 2
  repeat digits
    out(lookupz((value <-= 4) & %1111 : "0".."9",
"A".."F"))
```

Since a hexadecimal digit occupies four bits, we have to shift by four bits to align the most significant digit. After qualifying *digits* and subtracting that from eight, we shift the intermediate result by two — this is a more efficient way of multiplying by four. Our **repeat** loop works like it did in the *bin* method, except that we rotate *value* by four bits for each digit, AND with %1111, and finally use **lookupz** (zero-indexed **lookup**) for the correct digit character to print. A useful feature in **lookupz** is the ability to pass an implicit list of values requiring only the starting and ending points, hence "0".."9" replaces "0123456789." Note, too, that we can create a compound list by separating multiple lists and items with commas.

I think it's about time to put our *PC_Debug* object to work, don't you? In the archive you'll find a simple program called *PC_Debug_Test.spin*. It's pretty short, and with what we've already been through we can focus on the body of the program; the **CON** and **OBJ** sections are very straightforward.

```
PUB main | idx

  debug.start(460_800)
  debug.str(string(FF, "Debug Test", CR, LF, LF))

  repeat
    debug.hex(idx, 2)
    debug.out(Space)
    if ((++idx // 16) == 0)
      debug.crlf
  until (idx == $100)

  debug.crlf
  debug.dec(-1)
  debug.crlf
  debug.ibin(-1, 32)
  debug.crlf
  debug.ihex(-1, 8)
  debug.stop
```

There's only one public method in the program, and I've called it *main* — this is a style choice and not required. Remember, the first public method is what runs when a Spin program is launched. The first thing we do is start the *debug* object, and have a look at that baud rate: 460,800 — that is not a typo, that is 460.8 kBaud. Remember I said Chip's *FullDuplex* object was "high performance?" Now you can see what I'm talking about. And this is with a 5 MHz crystal connected to the Propeller chip.

The first thing printed is a string that is composed of a form feed character (clears the screen in HyperTerminal), some text, a carriage return, and a couple line feeds. All this is assembled with the *string* method which creates the inline string and returns a pointer (the address in memory of) to it. The string pointer is what's used by the *debug.str* method for printing. This is fine for one-off strings, but if we're going to use the same text more than once, it's better to embed it into a **DAT** block like this:

```
DAT

title   byte     "Nuts & Volts rocks!", 0
```

Note the zero terminator; this is important so don't leave it out. To print this string, we can pass a pointer to it with the @ operator.

```
  debug.str(@title)
```

The main body of the program is a loop that prints hex values from $00 to $FF in a 16 by 16 array. After printing the digit and a space, the value of *idx* is incremented and then tested with modulus to see if 16 values have been printed on the current line. If so, a carriage-return and line feed are inserted. The value of *idx* is tested at the end of the loop for termination.

Of course, there are several ways to skin this cat — we could have constructed the start of the loop like this:

```
  repeat idx from $00 to $FF
```

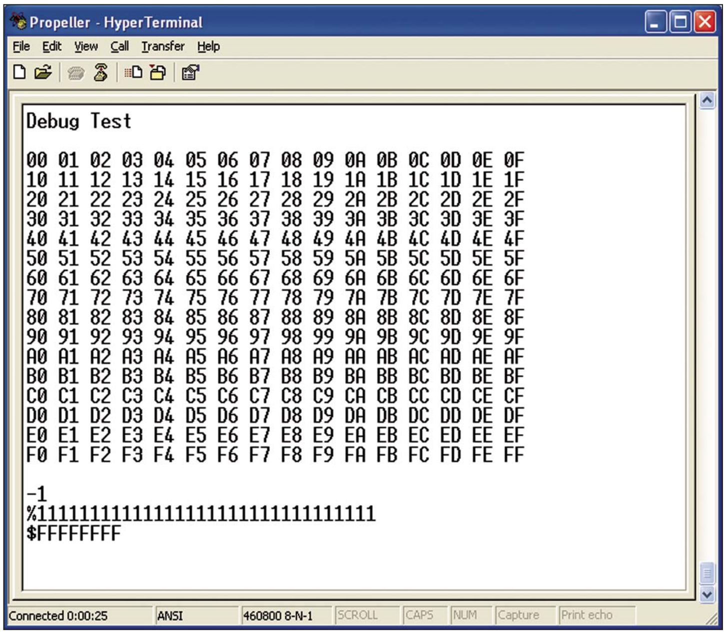


FIGURE 2. Debug Test Output.

Another option is to replace the **until** termination with:

```
  if (idx == $100)
    quit
```

My point is to show you that **repeat** — the only looping construct in Spin — is quite flexible and has a wide variety of options.

Okay, now that you've got a tool for sending values to a PC terminal program, it is time to play; you have enough to experiment with the Spin programming language and get used to it before we start connecting external hardware.

PROPELLER ARCHIVES

You'll notice that the ZIP that contains the files for this month has a very specific name; this ZIP was created by the Archive selection of the Propeller Tool > File menu. This is a tremendously useful feature of the IDE: it lets us gather and archive all the files of a project, no matter where the files are located on the system. This makes sharing projects with others a breeze as you are ensured that they will get everything they need. There's also an Archive feature that includes the IDE! With this you can open an archive folder several years from now and know that you've got what you need to recreate that project.

Have fun with your Propeller, and until next time ... Happy Spinning! And yes, we'll be back to working with the BASIC Stamp and SX very soon. **NV**

RESOURCES

JON WILLIAMS
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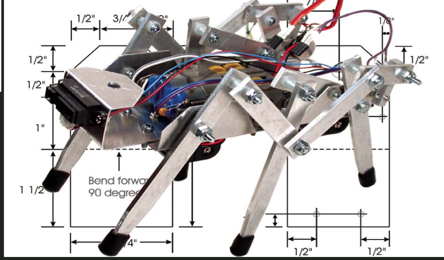
PARALLAX, INC.
www.parallax.com



BY PHIL DAVIS Co-written by Joe Stramaglia

ZEN AND THE ART OF ZIGBEE — PART 2

OKAY, LAST MONTH WE BRIEFLY DISCUSSED some of the architecture and network topology possibilities of Zigbee along with many of its capabilities. As promised, this month, I want to demonstrate a simple project in which a peer-to-peer Zigbee connection will be used to control a robot using simple commands and to receive data sent back from the robot.

For those just joining us, Zigbee is one of the new technologies designed to enable Wireless Personal Area Networks (WPAN) based around the new and emerging IEEE 802.15.4 standard. You might think of a WPAN (area) as your home or your backyard or perhaps your office space with you sitting at your PC and communicating to your robot, telling it to stop, start, turn left, etc., and your robot reporting back various bits and pieces of status information.

Hopefully, you took the opportunity since last month to follow some of the links and do a little research of your own. In case you didn't, now is a good opportunity to do so:

www.freescale.com/webapp/sps/site/prod_summary.jsp?code=ZRP-1&nodeId=01J4Fs25657103

http://zigbee.org/en/index.asp.

One of the design goals of this project was to use free software, riding piggyback, as much as possible, on previously written applications, to make controlling a robot via Zigbee fairly easy and accessible to most. You will have to purchase the Zigbee boards that we used, but for a fun project like this, they are well worth it.

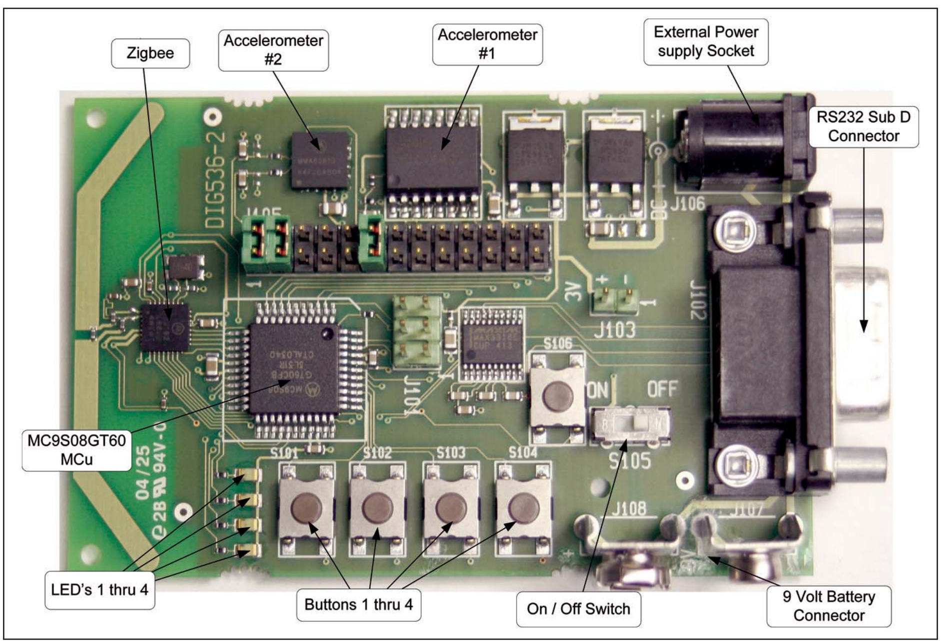
We also decided to focus on doing stuff with Zigbee, rather than on robot details. To this end, we decided to use as many off-the-shelf pieces as possible.

THE ZIGBEE BOARD

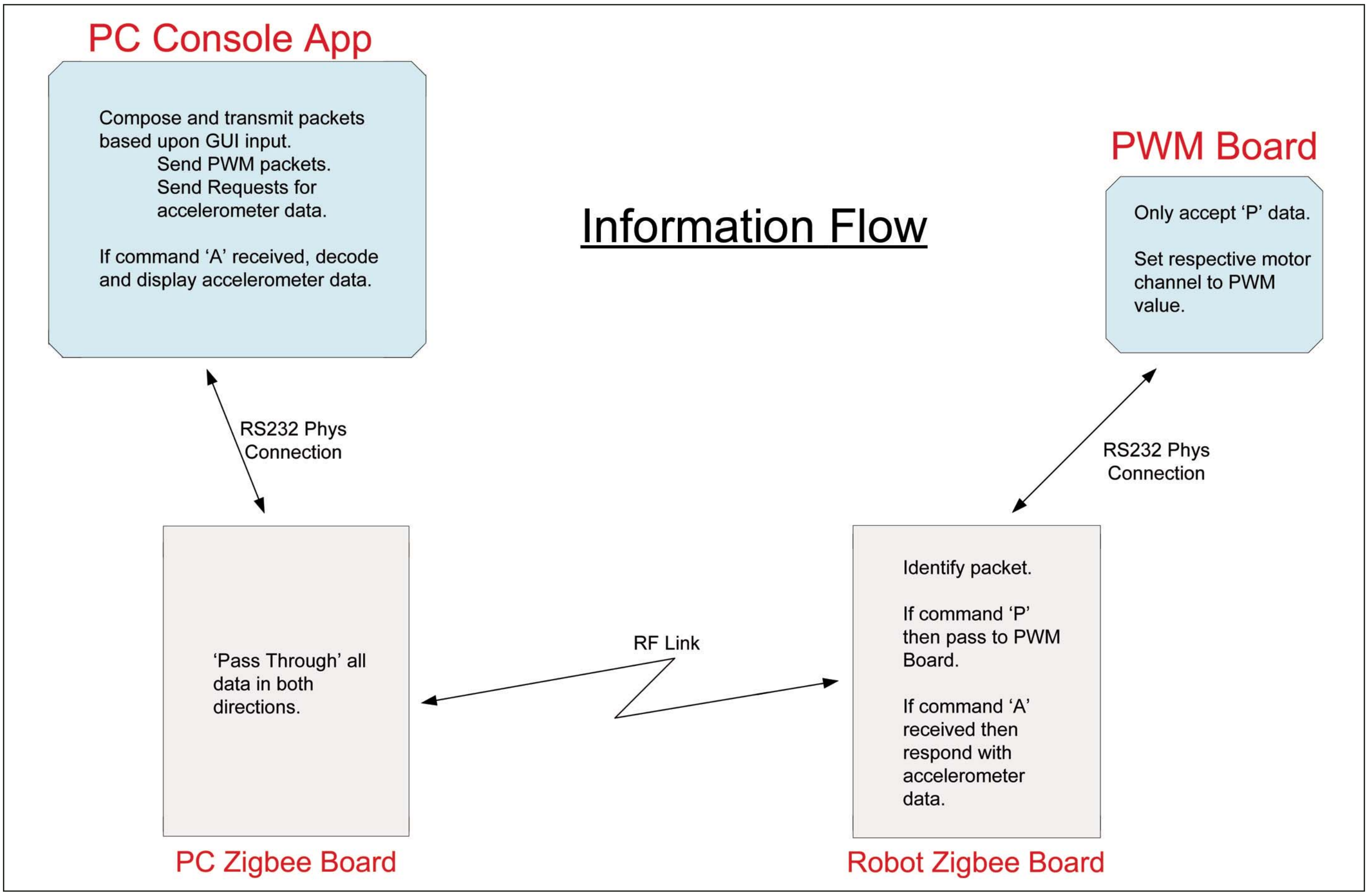
The Zigbee board we used was the 13192-SARD (shown in Figure 1), which is one of Freescale's development boards and may be purchased in pairs from Freescale (see the Resources sidebar for the URL).

From a robotics hobbyist point-of-view, this particular board has a lot of nice features:

- It has, of course, a Zigbee
- It has its own processor — the MC9S08GT60 — which executes the Zigbee stack
- It has RS232 built in to allow for communication to external boards and processors



■ FIGURE 1. Freescale Zigbee Demonstration Board.



■ FIGURE 2. Data flow between the PC and the robot.

• It has four buttons and four LEDs that your program can use to initiate or show various program functions

• It also has a built-in (which is too cool) three-axis accelerometer that you can access to send back to the PC the X, Y, and Z values caused by movement

With this board, you can run either a full Media Access Controller (MAC) or Freescale's Simple Media Access Controller (SMAC) software, which supports simple point-to-point and star networks and has a small memory requirement (less then 3 KB). Since we are doing a simple peer-to-peer communication link, we choose to use SMAC and besides, that leaves us with more memory left over for writing programs.

I said earlier that we tried to use off-the-shelf components. One of these was the 'UART' demonstration program. The UART demo app already interfaces with the Zigbee stack to do all the communication-protocol stuff and even 'acks' and 'nacks' packets as they are received, leaving us with little to do except layer our command-protocol structure, and any additional functions we want the robot to perform, on top.

THE COMMUNICATION PROTOCOL

Having decided which Zigbee board to use for this example project, the next thing to do was decide what capabilities we wanted the robot to have and how best to accomplish those, preferably providing expandability for future enhancements.

Minimally the robot should have:

• Differential drive (probably the simplest form of drive), i.e., one motor on each side, to allow forward and backward movement as well as steering

• Start/stop control

• Speed control

• The ability to send back information

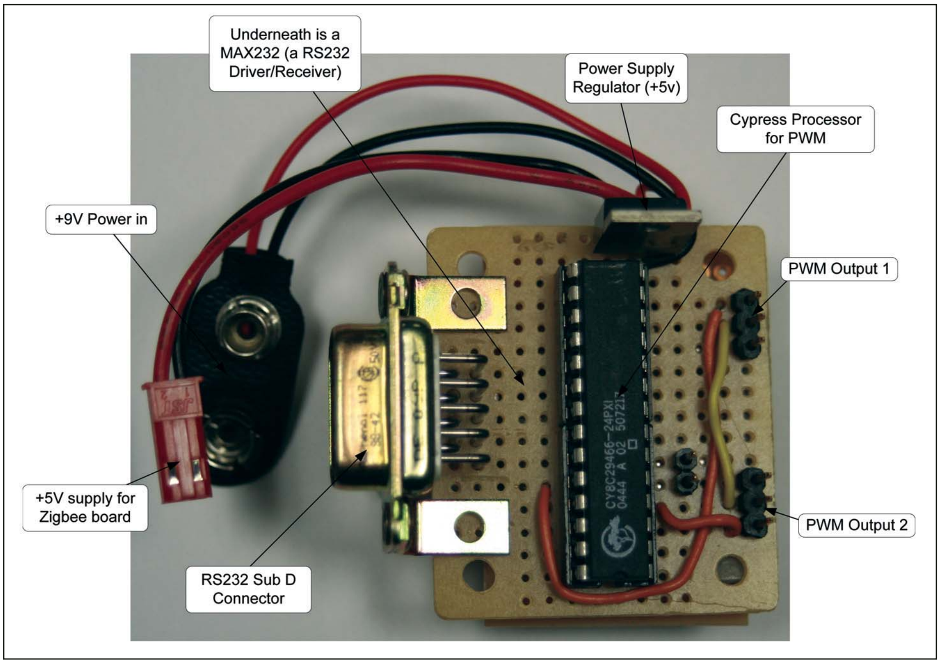
These features require a protocol structure for sending motor-control commands (and perhaps other commands) to the robot and also to request status and other information in reply. Below is the simple command protocol we came up with. It is composed of a packet containing a couple of 'start' bytes, a command byte, four bytes of data, and finally a trailing byte for a total of eight bytes.

Transmission from the PC to the robot:

• Two leading "**" to identify the start of the packet

• A command byte:
– "P" to send PWM data to the motors
– "A" to request accelerometer data

• Four bytes of data, padded if necessary



■ FIGURE 3. Our simple RS232/PWM board.

• A trailing "%" to signify the end of the packet

If the command byte is a "P" then the next byte is a "1" or a "2" referring to either motor one or motor two. The byte following that is the PWM value, which in our case is a range — "1" for full forward, "128" for stop, and "255" for full reverse.

Transmission from the robot to the PC:

• Two leading "**" to identify the start of the packet

• A command byte:
  – "A" for accelerometer data from the board

• Four bytes of data, padded if necessary

• A trailing "%" to signify the end of the packet

If the command byte is "A" then the next three bytes are the X, Y, and Z values retrieved from the accelerometer.

Whew! Glad that's out of the way. So now we have a way to tell the robot what to do and also a way for it to send us information. All this is layered on top of the demonstration UART application, which provides reasonably reliable communication. Figure 2 shows this data flow between the PC and the robot.

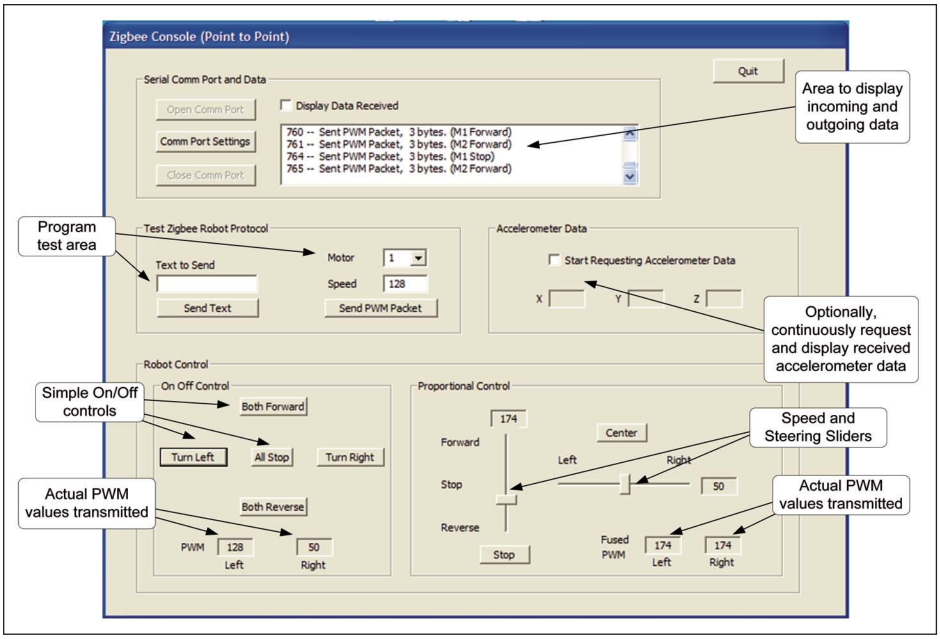
MAKING IT WORK

Okay. What does the Robot Zigbee board do once it receives a "P" command? Well, since we have access to RS232 for external communication, we quickly whipped up our very own small board, shown in Figure 3, to do the PWM output. We constructed this out of a Cypress CY8C29466-24P processor, because we had a few lying around, and wrote a few lines of code to accept the "P, motor-number, PWM" command from the Zigbee board and then to drive the correct output ports.

Although we built our own board, there are many small boards on the market today that will accept RS232 commands and drive sometimes as many as a dozen PWM channels, so, perhaps in the vein of using off-the-shelf components, that is a better way to go.

Alternatively, if the Robot Zigbee receives an "A" (a request for accelerometer data), it accesses the onboard accelerometer, packages up the X, Y, and Z values into the command structure, and sends them back to the PC.

To cause the above functionality to occur, all data coming back towards the PC is "passed through" the PC Zigbee and handled within the PC. Similarly, all data sent from the PC is again "passed through" the PC Zigbee and handled within the Robot Zigbee and any associated boards or processors. This will, of course, require some changes to the Robot Zigbee UART application, layering on top of our customized code to recognize command packets from the PC and to take the appropriate action: passing the correct data through to the PWM processor board or sending back



■ FIGURE 4. Command Console for Zigbee control.

accelerometer data as requested.

THE PC COMMAND CONSOLE

At this stage, we have conceptually (and physically) tied our PC through Zigbee to our Robot via a command protocol structure and a board to generate PWM signals at the robot end. This leaves the creation of the Command Console (shown in Figure 4) at the PC end to manage all of this. The Command Console's function is to provide a graphical interface for controlling the Robot and to receive and display any incoming data. To do so, it must talk to the locally connected Zigbee board via RS232.

There are several sets of functionality available through the Command Console. Most notable are the two areas to control the robot — the On/Off control area and the Proportional control area — and an area to display the received accelerometer data.

We included the On/Off control area in case simple motor devices such as Continuous Rotation Servos were attached. This control set will allow for the starting, stopping, and turning of the robot using these, by simply pressing the buttons.

The Proportional area is much more capable and allows for the continuous control of both motors through a range from full forward to stop to full reverse. This is done by moving either the speed slider or the steering slider in the appropriate direction.

There are two small windows at the bottom of these areas which show the actual Left and Right PWM values that are currently being transmitted to the robot. I should note that a transmission only occurs when a button is pushed or a slider position is changed. The PWM channels on the Cypress processor hold the last known PWM value, so there is no need for refresh. If that were not the case with the PWM output device in use, then the code would need to be modified accordingly.

Finally, there is the area which requests and displays the accelerometer data. Clicking the check box starts a timer that sends to the robot, 10 times a second, a request for data. When received by the console, this data is displayed in the appropriate windows.

The Command Console as it stands works as expected and is a reasonable base for developing further and more complex remote control Zigbee applications: it has the serial communication to the Zigbee board, the command structure for sending and receiving data, and some basic control functions.

TESTING THE SETUP

Hmmmm ... Well how did it all work? Good question! After some debugging here and there, everything worked pretty much as we had hoped. As shown in Figure 5, the PWM board was connected to the Zigbee board and to that were connected two continuous rotation servos.

Using this configuration, we were able to start and stop the servos, reverse them, and cause them to rotate in opposite directions, much as expected.

The next thing we did was connect the PWM outputs to a scope to see how the fully proportional aspects of the console worked. Sure enough, as we moved the sliders, the PWM square wave grew and shrank between 1-2 ms the way we had planned. I must admit, I was a little concerned that the Zigbee communication might fail if I quickly moved the speed slider up and down several times a second, causing many command packets (255 top to bottom) to be sent, but as far as we could see (eyeball), the proportional PWM continued to work quite smoothly. Not too shabby at all.

RESOURCES

■ You can purchase the SARD board directly from Zigbee at this link: **www.freescale.com/webapp/sps/site/prod_summary.jsp?code=13192DSK&parentCode=MC13192&nodeId=01J4Fs862825658166.**

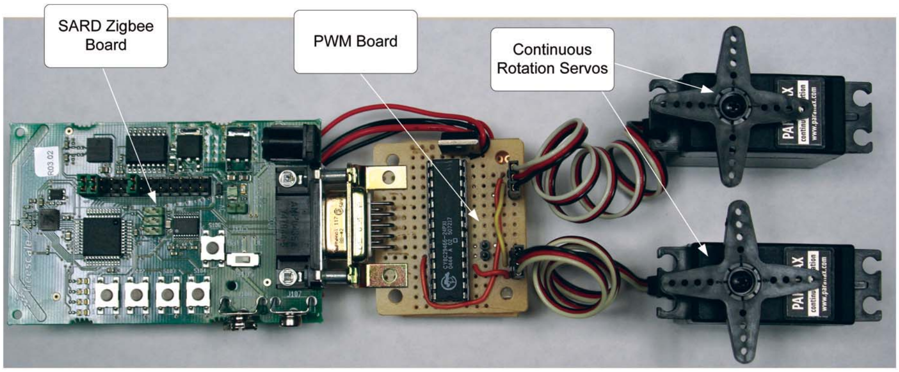
■ You can download the free Code Warrior development tool at this link: **www.freescale.com/webapp/sps/site/prod_summary.jsp?code=CWX-HXX-SE&parentCode=null&nodeId=01272694011860.**

■ You can get online help on Freescale Zigbee at the following forum link: **www.freegeeks.net/**

WHAT WILL IT COST?

So, can the reader do all this themselves and how much will it cost? Another great question! Well, except for the cost of the Zigbee boards, the compiler to modify and write additional code for the Zigbee boards is downloadable for free, though I believe in that form, it will only compile up to 16 KB of code. That is probably more than enough for hobbyists, especially if they are using it in a fashion similar to the way we did. In addition, the demonstration applications are free and may be modified and/or pieces of them included into your own programs.

Also, before the end of this three-part series (and possibly sooner), I will place on the *Nuts & Volts* website all the code we developed and used along with any circuit diagrams etc., which should hopefully give you a head start in devel-



■ FIGURE 5. All the components of the 'bot laid out in a row.

oping your own Zigbee application.

ENDNOTE

The command protocol discussed here is not designed to be either robust or efficient. There are many ways optimizations could be implemented, for example, make each command specific: the request for accelerometer data need only be four bytes long "**A%" or the 'P' command could set *both* motors at the same time, etc. Also, as it stands, if a command is for some reason not recognized, or not complete, it is simply thrown away, which is fine for this experimental project and most likely for many hobbyist applications. Enhancements are for the reader to experiment and play with.

Next month, we will tackle more advanced Zigbee topologies and hopefully we will have multiple robots running at the same time. **NV**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BY PETER BEST

FLIGHT TESTING THE ARM

WE GOT OUR ARM PROJECT TO "HOVER" LAST MONTH. This go-round, we're going to do a bit more flight testing. Right now, our ARM system consists of the bare essentials. For starters, we will add another serial port in addition to the existing serial port that is doing double-duty as the ICSP portal. We'll also design in a 20-pin JTAG interface that will allow us to go beyond the capabilities offered up by the free LPC2000 Flash Utility. I've noted the additions in the updated LPC2136 schematic (see Schematic 1).

If you've been around microcontrollers, it doesn't take very long to realize that the really important part of any microcontroller tool chain is the debugger. A good compiler makes life a bit easier on the coding side, but a good debugging system provides a bird's eye view of the microcontroller's CPU and internal peripherals. The big advantage of owning a good ARM debugging system is that if you're new to the ARM microcontroller and its associated compiler, you can use the debugger to halt execution of example code and study its operation and note what effects the code is having on the ARM hardware.

PHOTO 1. This unassuming little box holds the key to the magic of debugging and programming our LPC2136 using a JTAG interface. This is a must-have device as it can interface to an ARM target using free and more feature-rich licensed debugging tools.

As I alluded to earlier, a high quality C compiler will help you avoid some of the traps laid by lower quality C compilers that contain bugs and "gotchas" that can ruin your programming day. You get what you pay for and a higher quality compiler will most likely have fewer bugs and "gotchas" associated with it. And, you're probably going to get a better technical support structure with a quality C compiler you purchase from a proven C compiler vendor. Debugging is fun (at least to me it is), but all good things must come to an end. Once you're happy with your ARM code, you've got to put it into ARM Flash before it can be useful. Thus, a suitable ARM programming mechanism is also essential.

It is important to consider flexibility when collecting parts and pieces for your ARM tool chain. Do the ARM debugging and compilation components you've chosen allow you to move to other similar microcontroller platforms from differing manufacturers? Unless you work for Royal Philips, every ARM project you produce most likely won't include a Philips ARM microcontroller. Buying C compilers and debugging hardware for various types of ARM microcontrollers can get expensive. If you feel that you're going to do more than one ARM project, invest in quality tools. You'll find that you pay a bit more for a C compiler and debugger that can handle the whole ARM7 family. However, you'll also come to realize that it will cost you more to buy multiple cheaper C compilers and debugging tools.

I test drove a number of ARM C compilers and debuggers. One of the better sets of JTAG-based debuggers and supporting debugging software I came across is manufactured and produced by Segger. Segger also offers an ARM Flash programming system and the Segger programming/debugging software runs seamlessly with the ARM C compiler from IAR. I'm really anxious to show you the cool ARM stuff I've discovered. So, let's take a look at my collection of Segger/IAR ARM tools.

THE SEGGER J-LINK FOR ARM

Although my J-Link sports an IAR

moniker, it's actually a Segger J-Link. The Segger J-Link device you see in Photo 1 is the 20-pin link between us (the ARM system programmers) and our target ARM hardware. The J-Link gets its power from the USB connection and supports every ARM7 device that we have discussed thus far in both 32-bit and thumb modes. The J-Link includes a feature set that operates unconditionally with the IAR Workbench.

If you decide not to implement the full 20-pin JTAG interface in your design, the J-Link can operate in both 20-pin and 14-pin JTAG configurations. Segger sells a 14-pin JTAG adapter for this purpose. However, you can "garage manufacture" a suitable 14-pin JTAG adapter on your home bench using the JTAG pinout information that is found on the Segger website (www.segger.com). In fact, the Segger website is a good place to visit if you're thinking about doing anything with ARM microcontrollers.

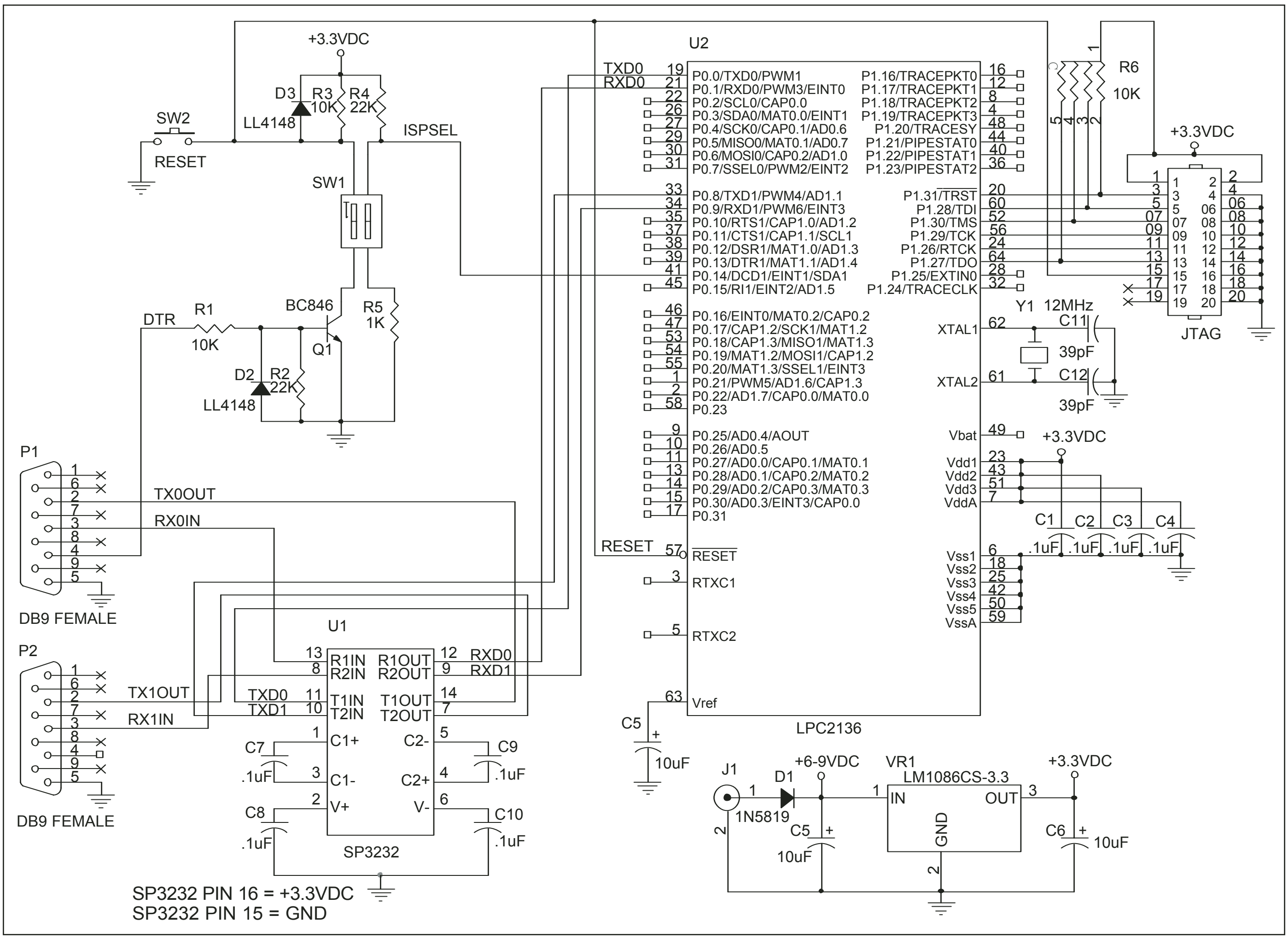
Segger's J-Link for ARM is supported by Windows 2000 and Windows XP via a full speed USB 2.0 interface. No burden is placed on the personal computer's USB power supply or your target ARM system as the Segger J-Link operates with less than 50 mA of current. The maximum transfer rate is between the J-Link and the LPC2136 target is 12 MHz. So, there will be no time for smoking and drinking between debug spins. J-Link supports ARM devices that can accept power supply levels between 1.2 VDC and 3.3 VDC. If you need to design in a 5 VDC ARM device, Segger offers a ready-to-roll 5 VDC adapter.

USING THE SEGGER J-LINK FOR ARM

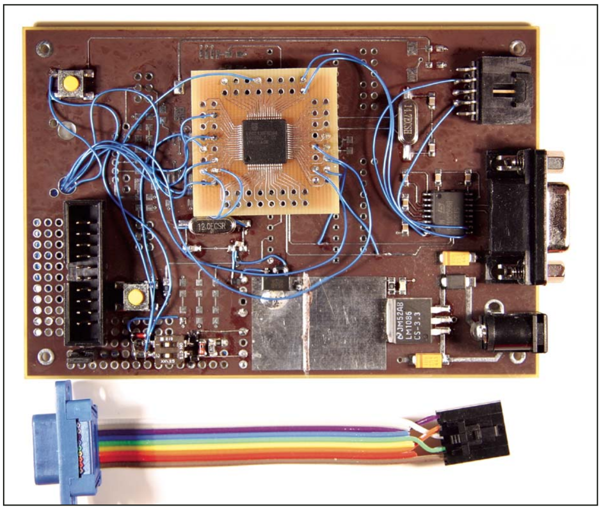
In the first installment, we certified our new LPC2136 design with the LPC2000 Flash Utility. Now it's time to take the next step and integrate the Segger J-Link into our LPC2136 C coding, programming, and debugging strategy. Segger offers a set of free ARM7 tools in addition to its licensed ARM7 offerings. I happen to have the entire set of Segger licensed and unlicensed tools. So, let's take a first-hand look at what Segger has to offer.

I've downloaded the free J-Link ARM package from the Segger website and installed it on my PC. Let's put our newly added LPC2136 JTAG interface to the test. I attached my J-Link to the updated LPC2136 prototype board (Photo 2) we've been building up. I prepared myself for a possible smoke session and applied power to the upgraded LPC2136 prototype board.

After powering up, I checked out



■ SCHEMATIC 1. Adding the JTAG interface and the second serial port completes the base hardware design for the LPC2136 Development Board.



■ PHOTO 2. This board is getting pretty busy. If you compare this photo to the one in last month's Design Cycle, you'll note the addition of the 20-pin male header, which is the JTAG interface for the J-Link and an extra three-wire serial port. Because I have "recycled" the base printed circuit board, I constructed a serial cable extension to mate with the five-pin Berg connector that is standing in for a standard DB-9 female shell connector.

the LPC2136 prototype board's communications capability one more time with the LPC2000 Flash Utility just to make sure I hadn't fouled anything up with my JTAG interface installation. Everything checked out fine and I didn't release any magic smoke from any of the LPC2136 prototype board's components. I then attached my J-Link to the LPC2136 prototype board's new 20-pin JTAG connector and reapplied power to the prototype board. I also connected a USB cable between the J-Link and my PC. The J-Link status LED started to blink indicating that the J-Link ARM was enumerating. When the J-Link status LED transitioned from blinking to solid, that was my cue that the J-Link had enumerated successfully and was ready to go.

For those of you that are not familiar with USB, USB devices perform an enumeration operation to establish a communications session with a host controller. Lots of capability and configuration information is passed between the enumerating device and the host during the enumeration process. The enumerating device passes through four states: Powered, Default, Address, and Configured. If everything goes as planned within each state, the enumerating device becomes available to the user and application program.

With the LPC2136 development board and J-Link seemingly on the ready, I kicked off the free J-Link Commander application. As you can see in Photo 3, the LPC2136 on the LPC2136 prototype board was recognized by J-Link Commander. The J-Link ARM hardware was also detected and, as you can see in the screen shot, my LPC2136 produced an ARM core ID of 0x4F1F0F0F. Things are very good for us right now as we have established a navigable portal into the innards of the LPC2136.

The J-Link Commander application is a very useful tool and allows the user to stop and start the LPC2136, as well as read and write the LPC2136's memory. One can also inspect various memory locations and registers of the LPC2136. To give you an idea of how memory inspection looks and works within the J-Link Commander application, I dumped the first 100 bytes of the LPC2136 Flash for you in Photo 3.

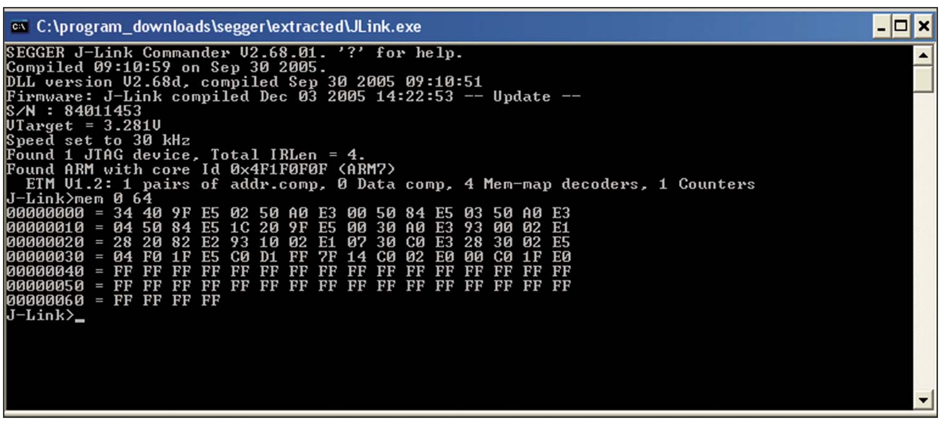
Although you can use J-Link Commander to alter the LPC2136's memory contents, there's a better tool for reading and writing the LPC2136 memory areas and it's a free download, as well. The free Segger ARM memory inspection and alteration tool is called J-Mem. Used with the J-Link ARM device, Segger's J-Mem displays the LPC2136's memory contents and allows modification of the LPC2136 registers and SRAM in real time.

A J-Mem Flash and SRAM memory dump is shown in Photo 4. The LPC2136 Flash dump begins at address 0x0, while LPC2136 SRAM begins at address 0x40000000. As you can see in the SRAM dump, I inserted some text at the beginning of the LPC2136's SRAM space. I did this by simply typing in the text in the ASCII area of the J-Mem window.

The free J-Link Commander and J-Mem applications can run at the same time. So, to prove that J-Mem had indeed written the LPC2136's SRAM, I used J-Link Commander to dump the first 100 bytes of the LPC2136's SRAM. If you check each byte I entered in the J-Mem SRAM dump with the J-Link Commander SRAM dump, you'll see that the SRAM on-the-fly memory alteration worked as designed. J-Link Commander and J-Mem are good tools. It gets better ...

SEGGER'S J-LINK RDI

The Segger free tool set works great but if you want to get serious, you'll need to move into the licensed tool quadrant. J-Link RDI is an extension of the RDI (Remote Debug Interface). RDI is a standard set of debugging data structures and func-



```
C:\program_downloads\segger\extracted\JLink.exe
SEGGER J-Link Commander V2.68.01. '?' for help.
Compiled 09:10:59 on Sep 30 2005.
DLL version V2.68d, compiled Sep 30 2005 09:10:51
Firmware: J-Link compiled Dec 03 2005 14:22:53 -- Update --
S/N : 84011453
VTarget = 3.281V
Speed set to 30 kHz
Found 1 JTAG device, Total IRLen = 4.
Found ARM with core Id 0x4F1F0F0F (ARM7)
  ETM V1.2: 1 pairs of addr.comp, 0 Data comp, 4 Mem-map decoders, 1 Counters
J-Link>mem 0 64
00000000 = 34 40 9F E5 02 50 A0 E3 00 50 84 E5 03 50 A0 E3
00000010 = 04 50 84 E5 1C 20 9F E5 00 30 A0 E3 93 00 02 E1
00000020 = 28 20 82 E2 93 10 02 E1 07 30 C0 E3 28 30 02 E5
00000030 = 04 F0 1F E5 C0 D1 FF 7F 14 C0 02 E0 00 C0 1F E0
00000040 = FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000050 = FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000060 = FF FF FF FF
J-Link>_
```

■ PHOTO 3. This is good to see. This window confirms the existence of both the J-Link ARM hardware and the LPC2136. At this point, we can use the J-Link Commander application to turn some of the LPC2136 register and SRAM knobs.

tions aimed at the ARM hardware model. RDI is implemented by Segger as an API (Application Programming Interface) that is distributed as a standard Windows DLL. Any RDI compliant debugger can access the services of Segger's J-Link RDI DLL.

Up to this point, the LPC2136 and its cousins have been presented as super microcontrollers. Even with all of that Flash and SRAM space coupled with ultra high speeds, ARM hardware only supports two hardware breakpoints. This can present a programmer efficiency problem as some debuggers are designed to only operate in SRAM.

Walking along a large amount of code with only a couple of breakpoints makes for a long debugging day. Most microcontrollers have far more Flash than SRAM. Thus, it may be difficult or impossible for a standard SRAM-based debugger to load all of the necessary program and data into the SRAM area for debugging. The J-Link RDI brings the LPC2136 and company back to hero status by providing unlimited breakpoint capability while operating in Flash or RAM.

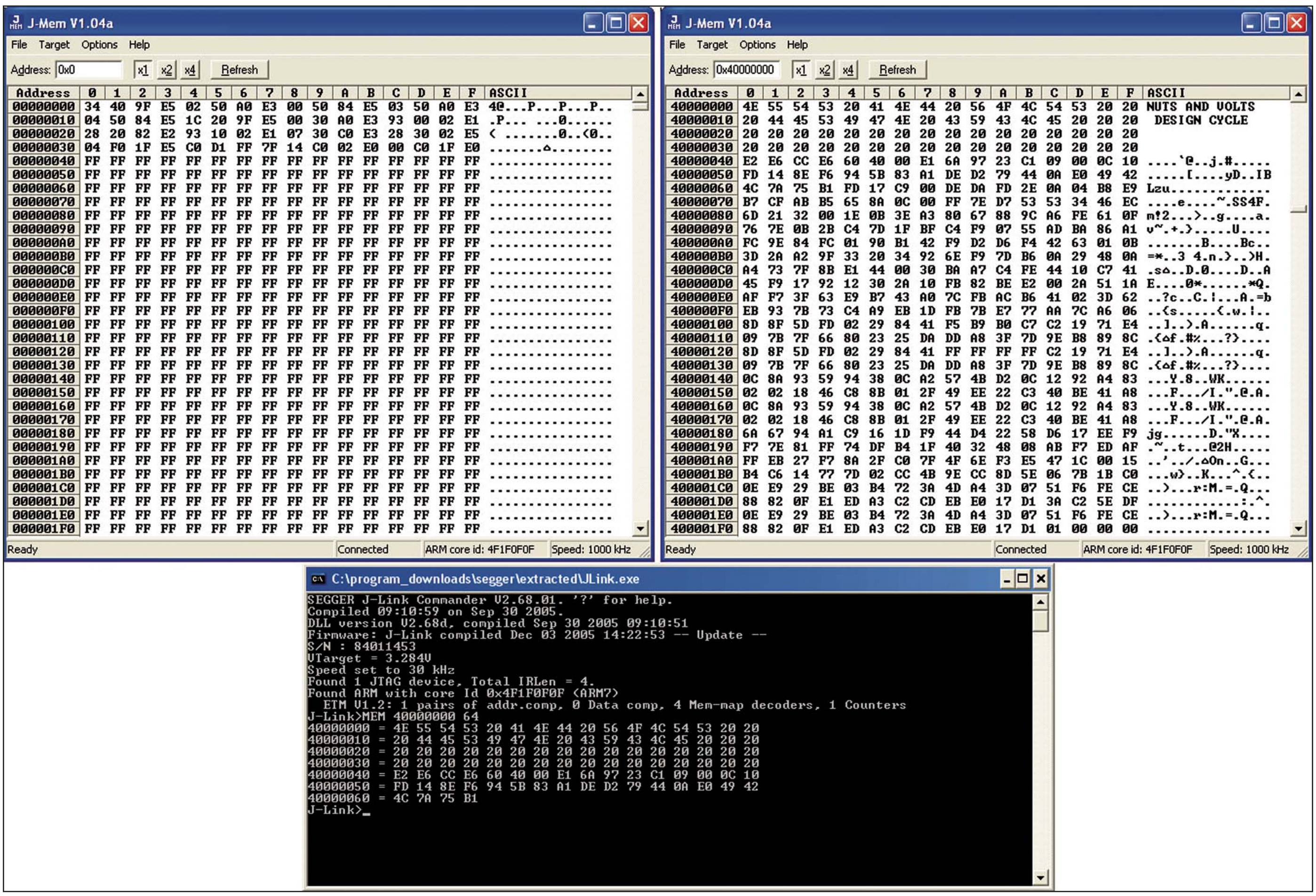
J-Link RDI's ability to provide unlimited breakpoints is made possible by the implementation of software breakpoints. Hardware breakpoints do not depend on code to operate as they are part of the hardware architecture. On the other hand, software breakpoints are implemented as minor changes to the actual binary code.

A software breakpoint is created when the debugger modifies the original program code at the desired breakpoint location by replacing the binary code at the breakpoint location with a special breakpoint value. Thus, multiple software breakpoints can be placed at any instruction boundary within the fabric of the binary code. The firmware must be modified to create a software breakpoint. So, it's obvious that software breakpoints are most suitable to be placed within the binary code that resides in SRAM.

To provide SRAM-like software breakpoints in Flash, the J-Link RDI software uses a small SRAM-based application to reprogram a sector of Flash that sets or clears a software breakpoint in Flash memory. To preserve the life of the LPC2136 Flash memory cells, J-Link RDI only programs Flash sectors when it is absolutely necessary. Many times only a single sector has to be programmed as multiple software breakpoints are often located in the same Flash sector.

Even though software breakpoints are being utilized, hardware breakpoints are included in the mix as well, when they can be used efficiently by the J-Link RDI. A built-in

■ PHOTO 4. The first 64 bytes of code you see in the Flash dump (address 0x0) make up the interrupt vector area. This area of code is always remapped to 0x00000000 thru 0x0000003F. We'll talk more about this code area later. The LPC2136 SRAM begins at address 0x40000000 and I've used a bit of it as a billboard in this shot. Note that I dumped the SRAM in the J-Link Commander window to prove a point.



LISTING 1:

This code initializes the LPC2136's UART1. If this doesn't make much sense to you now, don't worry. By the time we're done with our LPC2136 Design Cycle, you'll be right at home with this code.

```
/*Configure the pins that are connected to RX and TX on UART1 */
 PINSEL0 = (1<<ENABLE_UART1_RX) | (1<< ENABLE_UART1_TX); // PINSEL0 = 0x50000

 /*Configure UART1 to 9600 buad, 8 bit, 1 stop, no parity */
 U1FCR = 1;                                       // Enable FIFOs whether used or not
 SetBit(U1LCR,DIVISOR_LATCH_SET_bit);             // U1LCR = 0x80-enable access to divisor
                                                  // latch bit, necessary for setting baud rate
 U1LCR |= EIGHT_BIT_CHARS;                        // Eight bits U1LCR = 0x83
 ClrBit(U1LCR,PARITY_ENABLE_bit);                 // No parity
 ClrBit(U1LCR,STOP_BIT_SELECT_bit);               // One stop bit
 U1DLL = 19;
 U1DLM = 0;                                       // Clear msb of divisor latch
 ClrBit(U1LCR,DIVISOR_LATCH_SET_bit);             // Disable access to divisor latch
```

instruction set simulator also offloads some of the software breakpoint duties, which eliminates the need to reprogram a Flash sector. J-Link RDI provides the LPC2136 programmer with an unlimited number of software breakpoints and absolutely no memory or peripheral subsystem loss to the debugger. Wow!

THE IAR EMBEDDED WORKBENCH

I have an assortment of ARM C compilers and they all have their strengths. However, I had no luck in getting any of my ARM C compilers to recognize the J-Link RDI DLL. Even though the C compilers are very high quality, they are obviously not RDI compliant. At this point in time, I didn't have a copy of the IAR Embedded Workbench. Since the IAR Embedded Workbench and associated compiler are available for free, and I know that the IAR Embedded Workbench works with the J-Link RDI and J-Link ARM hardware, I decided to go for it. The free version of the Workbench only supports code sizes up to 32K. That's fine for us right now.

EXERCISING THE LPC2136 SERIAL PORT

Let's install all of the Segger and IAR tools and see if we can get some characters to flow from the newly installed serial port. In addition to the free J-Link utilities and the IAR Embedded Workbench, I installed licenses for J-Flash ARM and J-Link RDI. Additional functionality was added to the J-Link RDI package with the inclusion of Flash breakpoints (FlashBP) and Flash download (FlashDL).

FlashDL adds the capability of directly downloading to Flash from within the RDI framework. J-Flash is a programming tool and provides a means to view, erase, program, read, write, verify, checksum, and memory fill internal and external Flash memory using the J-Link ARM.

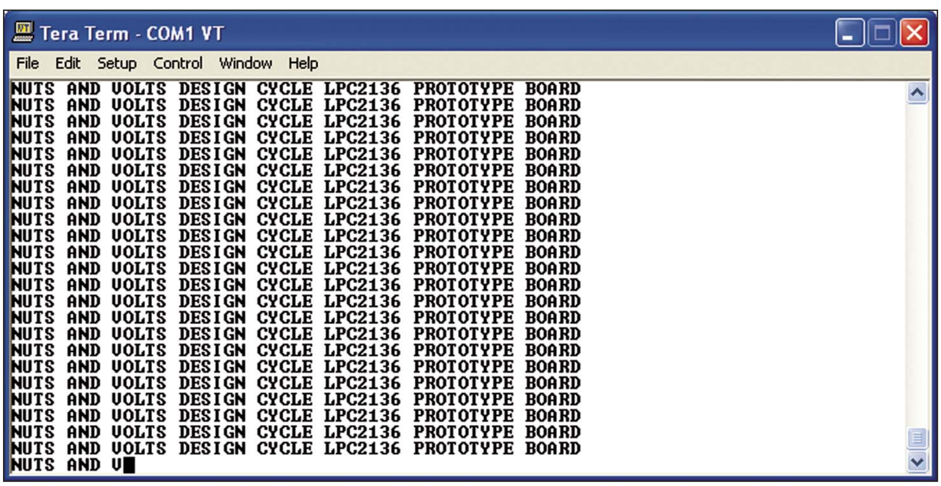
The serial port is a very important part of my development boards as I use the serial port as a debugging tool, as well. In an effort to prove the serial port hardware, I've written some code to spit some characters out of our new LPC2136 serial port. Running the serial port code will also validate the rest of the LPC2136 prototype board's hardware we haven't tested as we'll also exercise the new JTAG port.

The code snippet that configures the LPC2136's UART1 is shown in Listing 1. I tied some supporting code around the Listing 1 code snippet and produced the output you see in Photo 5. The complete LPC2136 UART1 code will be available on the *Nuts & Volts* website (**www.nutsvolts.com**).

THE NEXT STEP

You can get 30-day trial versions of all of the Segger J-Link ARM licensed products I've talked about. So, get yourself a J-Link ARM so you can use the free J-Link Commander and J-Mem utilities along with the licensed J-Link products to learn more about the LPC2136.

The Design Cycle is a hands-on column and if you want to follow along step-by-step, you can either build up an LPC2136 Development Board from scratch as I have done, or you can catch me next time as we'll be converting our point-to-point hardware to a full-blown (and cheap)



■ PHOTO 5. This is the first milestone. The LPC2136 Development Board hardware works as designed. We're ready to put the point-to-point design down on a printed circuit board.

printed circuit board version of the LPC2136 Development Board. Either way, I'll make printed circuit boards and all of the parts you'll need available to you via the EDTP Electronics website (www.edtp.com).

I'll also have my programmer hat on in the next installment of Design Cycle. After we walk through the assembly of our new LPC2136 Development Board, we'll investigate what it takes to write an LPC2136 C program and put some more of the LPC2136 hardware through its paces.

As always, feel free to contact me at peterbest@cfl.rr.com with any questions you may have. After all, it's my job to help you put an ARM microcontroller into your Design Cycle. **NV**

ABOUT THE AUTHOR

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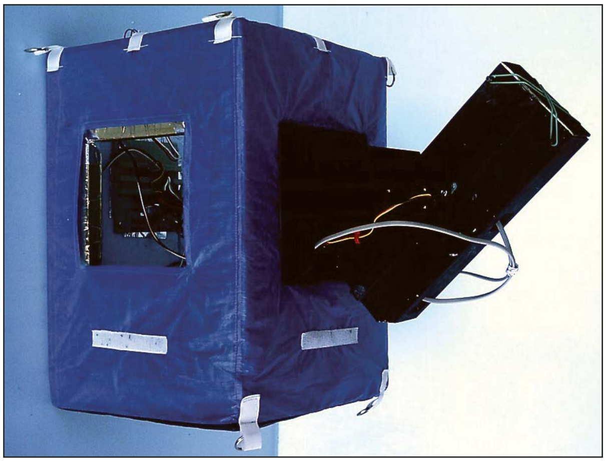
■ BY L. PAUL VERHAGE

THE NEAR SPACE GEIGER COUNTER TELESCOPE — Part 1

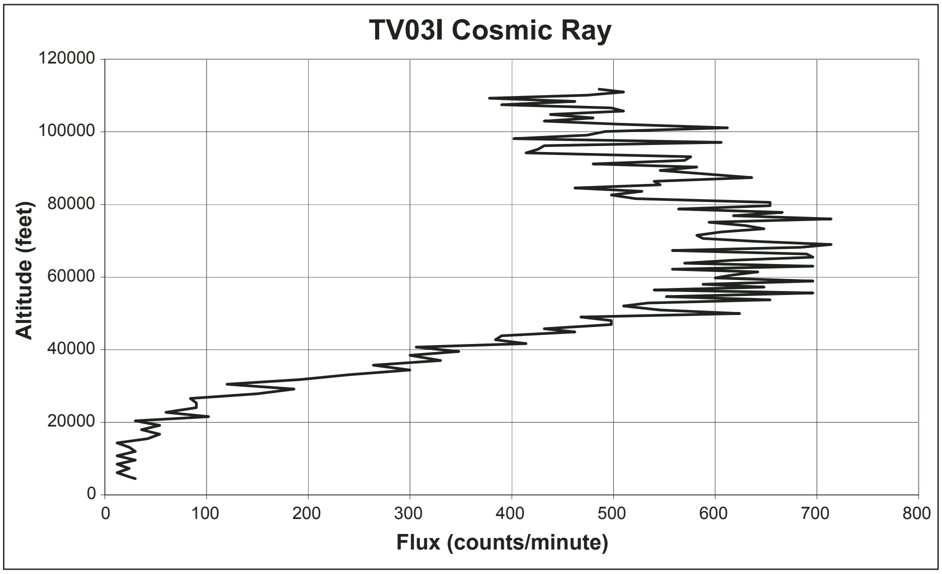
MANY OF MY NEAR SPACE MISSIONS have measured the cosmic ray flux in near space with onboard Geiger counters. Combining Geiger counter data with GPS altitude has allowed me to generate charts showing the cosmic ray flux as a function of altitude. Experiments like this allowed the Austrian physicist Victor Hess to prove the existence of cosmic rays in 1911-1913.



■ FIGURE 1. A mission-ready Geiger counter telescope.

The chart in Figure 2 is an example of the cosmic ray data from my near space flights. Notice that the cosmic ray count rises from about eight counts per minute (CPM) at the surface (an elevation of 2,400 feet at home) to a maximum of around 700 CPM at an altitude of 62,000 feet. Surprisingly though, the cosmic ray count decreases above 62,000 feet.

■ FIGURE 2. Example of cosmic-ray data.



It took me a few days to discover why the cosmic ray flux decreases at the highest altitudes. When a cosmic ray enters Earth's atmosphere, it slams into a molecule in the air and shatters it. This collision creates a shower of secondary cosmic rays that continue towards the surface. A secondary cosmic ray can create additional secondary cosmic rays though collisions. The decreased cosmic ray flux above 62,000 feet is therefore an indication that only original (primary) cosmic rays are being detected. They haven't yet had a chance to collide. After enough collisions, however, most secondary cosmic rays have so little energy that they are undetectable at the Earth's surface. So on the surface, we're detecting only those cosmic rays that survived collisions with molecules in the air.

This introduction has so far discussed only the history of a cosmic ray after it enters our atmosphere, not what a cosmic ray is. Most cosmic rays are hydrogen nuclei or protons. There are also some helium nuclei (alpha particles) thrown into the mix along with the nuclei of heavier atoms, energetic electrons, and a few gamma rays. Where does this zoo of subatomic particles come from? Today it's believed they originate in supernova explosions and from the sun.

Subatomic particles, such as protons and electrons, gain energy and change their direction of travel if they drift through a supernova's powerful shockwave. Repeated passages through the shockwave impart tremendous energy to them until they are energetic enough to escape the magnetic fields of a supernova explosion. At this point they become cosmic rays. Most cosmic rays travel around the galaxy because they don't have the energy to escape its magnetic field. They create the background radiation that permeates outer space.

The sun's activity is a second source of cosmic rays. When events like solar flares occur, radiation levels in space can rise dramatically. Sometimes satellite electronics are damaged by this radiation. Some solar events increase the risk of radiation poisoning for astronauts residing outside the Earth's protective magnetosphere, so Mars-bound astronauts will have radiation-storm shelters onboard their spacecraft.

Because of their differing histories, cosmic rays carry a wide range of energies. The lowest energy ones are weak enough that a thin-skinned spacecraft can shield astronauts inside. However, some of the ultra-high energy (UHE) cosmic rays are real animals. One UHE cosmic ray was detected carrying the same energy as the fastest thrown baseball. Think about that. We're talking about the energy of a baseball traveling at over 100 mph inside a single subatomic particle. If its energy could be captured inside a thimbleful of water, the water would boil instantly. A thimble of water doesn't stop cosmic rays of this energy. In fact, a UHE cosmic ray would hardly notice that the thimble existed as it plowed through it. These powerful cosmic rays may originate from the most monstrous objects in the universe — massive black holes in the centers of galaxies with active nuclei. However, because of the Big Bang's pervasive cosmic microwave background (CMB), a UHE cosmic ray must originate in a nearby galaxy. A UHE cosmic ray will lose its energy through collisions with the CMB's photons if it encounters too many.

Counting cosmic rays amazes me. Every "click" of my Geiger counter is the detection of a single cosmic ray. This means that at high altitudes, my cosmic ray experiments are detecting individual atoms from another star. Having flown numerous cosmic ray detectors on near space missions, I'm now looking for new ways to fly these experiments. While I haven't found a way of determining cosmic ray energies, I now have a way to determine their direction. So this month I'll describe my Geiger counter telescope. In the next article you'll be able to read about its testing and results.

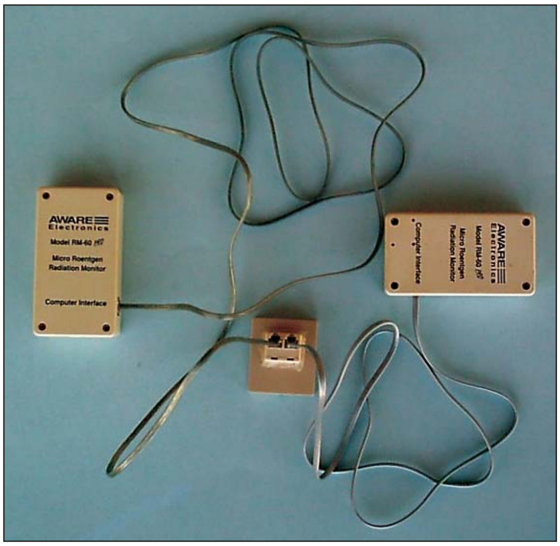
THE PROBLEM OF THE SINGLE GEIGER COUNTER

Geiger counters can only detect ionizing radiation. Inside each Geiger counter is a Geiger-Muller (GM) tube — a metal tube filled with a low-pressure gas (or combination of gases). Running through the center of each GM tube is a wire. The circuitry of the Geiger counter creates a potential difference between the wire and the tube's metal jacket. While large, the potential difference is still small enough that current can't travel across the gap between the wire and the tube. A particle of ionizing radiation passing through the tube creates a channel of ionized gas. The channel of ionized gas creates a path that allows some electrons to flow between the tube and the wire. The flow of these first few electrons knocks more electrons off the gas molecules inside the tube, allowing more electrons to flow through the channel. That current is amplified by the Geiger counter's circuitry, creating the click-click of bad science fiction movies.

A process called quenching eventually stops the flow of electrons between the center wire and the metal jacket. Without quenching, the gas inside the GM tube would remain ionized. With a GM tube filled with ionized gas, a Geiger counter is unable to detect any additional ionizing radiation traveling through it. The time required to quench a GM tube is called its dead time. The shorter the dead time, the more frequently radiation can be detected by the GM tube. The dead time of my Geiger counter is 20 µs. Therefore, my Geiger counter can detect up to nearly 50,000 CPM (assuming that the radiation events are evenly spaced apart). Of course, this represents a nuclear-war level of radiation. So if I detected a count rate this high, I wouldn't be around long enough to wonder what was going on.

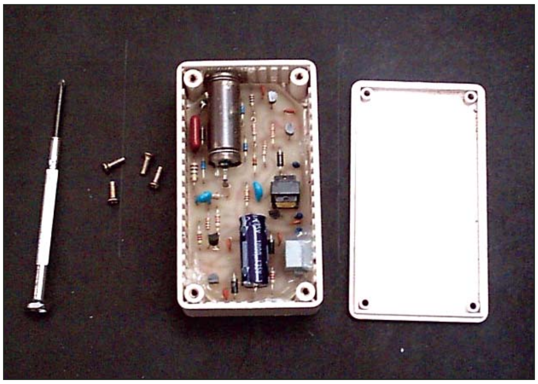
Geiger counters are insensitive to direction because ionizing radiation from any direction is capable of triggering an output. So unless some kind of trick is employed, there is no way for a Geiger counter to determine the source or direction of the radiation. One method used to determine the source of radiation is to walk closer to the potential source and listen for a corresponding increase in detected radiation.

There's another way to detect the direction of radiation, and that's with the coincidence counter. A coincidence counter is an AND gate employed between two or more Geiger counters. Two Geiger counters will produce simultaneous outputs only when an ionizing subatomic particle passes through both detectors *and* the particle passes through both GM tubes during their dead times.



■ FIGURE 3. Two RM-60 Geiger counters and their coincidence counter.

■ FIGURE 4. Aware Electronics' RM-60 Geiger counter.



■ FIGURE 5. Inside the RM-60. The GM tube is located at the upper left of the box.

Note that in a high-radiation environment, there can be simultaneous, but unrelated detections. Think of the coincidence counter as filtering out the non-simultaneous signals and passing only the simultaneous ones. Now, if the relative positions of both Geiger counters are changed, then so is their direction of sensitivity. I've used this principle to assemble a Geiger counter telescope capable of measuring changes in cosmic ray flux as a function of elevation in the sky.

BUILDING THE GEIGER COUNTER TELESCOPE (GCT)

Mine's not the first. The Pioneer 10 spacecraft — the first spacecraft to travel beyond the asteroid belt to Jupiter — carried a Geiger counter telescope to measure the flux and direction of radiation in the distant solar system. My near space GCT holds two Geiger counters that are fixed relative to one another. The GCT is able to change their pointing direction because I mounted the two Geiger counters inside a tube that a servo can rotate into any elevation. The outputs from each Geiger counter are routed to their coincidence counter inside the near spacecraft. The flight computer inside the near spacecraft commands the servo to rotate the tube to a new elevation and records the output of the coincidence counter along with the current GPS altitude.

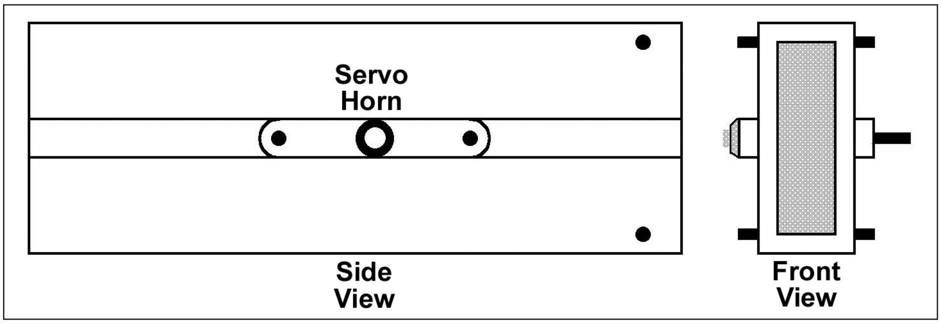
Before describing how to build the GCT, let me first explain what kind of Geiger counter I use. Aware Electronics manufactures the RM-60 Geiger counter. The RM-60 operates over a PC or laptop serial port. Not only does it send data over the serial port (as a series of five-volt pulses), but it also gets its power over it. The RM-60 is a very smart and compact design. It's the perfect Geiger counter to interface to a microcontroller like the BASIC Stamp. The RM-60 weighs 3.8 ounces and measures 2.45" wide, 4.45" tall, and 1.25" deep. There are three wires in its serial connector: +5V, ground, and pulse. Its serial cable is a telephone cable terminating in a RJ-11 connector.

I started this project by building the GCT tube first. Then I built the GCT mount around the tube. The tube is constructed from 1/4" balsa sheet. The four sides of the tube are cut large enough that the completed tube can hold two RM-60s, one above the other, with a 1/2" head space above the top Geiger counter. The bottom of the tube is sealed, and the top is left open. The RM-60s fit tightly enough inside the tube that I had to drill a small hole in the center of the tube's bottom to let me push the RM-60s out with a dowel or pencil (using the eraser end).

This tube rotates around its middle to limit torque acting on the elevation servo. But if I drilled two holes into the 1/4" balsa and mounted the axle into the balsa, it would most likely crack the tube. So I epoxied a 1/2" by 1/4" basswood strip along the midline of the tube for the axle. The basswood strip is stronger than the balsa and will not break when the axle is mounted to it.

Because there's no room between the RM-60s, the axle does not go fully through the GCT tube. The axle is in two pieces and they're only mounted into the basswood strip. One half of the axle is a 1/4" wooden dowel that extends one inch beyond the GCT tube. This axle dowel freely rotates within a hole in the GCT mount, which I'll describe later. The other half of the axle is a servo horn that is bolted to the basswood strip. The servo horn attaches to the elevation servo that is mounted into the GCT mount.

To prevent the RM-60s from falling out of the GCT tube, the tube's opened end is sealed with a cap of Styrofoam and plywood. The Styrofoam is 1/2" thick and fills up the remaining head space inside the GCT tube. A 1/8" thick modeling plywood plate epoxied to the Styrofoam helps keep the cap in place and prevents the rubber bands from cutting into the Styrofoam. Two holes are drilled through the end of the GCT tube. Dowels, epoxied through the holes, are the hooks that rubber bands wrap around to hold the



■ FIGURE 6. Front and side views of the GCT tube. The center of the servo horn lines up with the dowel on the opposite side of the GCT tube.

GCT cap in place in Figure 7.

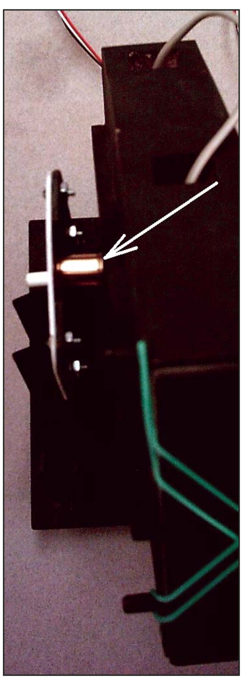
The GCT tube is finished by cutting small holes into it over the RJ-11 jacks in the RM-60s. These holes are where the RM-60 serial cables exit the GCT tube.

Now that the tube is completed and its final dimensions known, it's time to begin work on the GCT mount. The GCT mount is essentially a pair of arms that hold the axle of the GCT tube. One side of the GCT tube axle rotates freely in the mount and the other side of the GCT tube axle engages the elevation servo in the mount.

On my near spacecraft, the GCT mount is attached to a plate of plywood and Styrofoam that I call a quad port. My design is fully described in my near space book at the Parallax website (**www.parallax.com/html_pages/resources/custapps/app_nearspace.asp**). You may decide to adopt a different standard for your near spacecraft airframes, and if so, you'll need to attach your GCT mount differently than I do.

My GCT mount is constructed from 1/8" modeling plywood. The sheets are epoxied together to form a pair of rigid arms. The arms must be rigid or else the GCT tube will drop out of the mount. That's not a good thing at 100,000 feet. Figure 8 shows the design I used for my GCT mount.

Now the GCT tube is complete, so we can make sure the arms are long and wide enough. The arms of the GCT mount must be long enough that the elevation servo can reach the servo horn in the tube. The width of the arms is partially controlled by the size of the elevation servo. But by making them wider, we can increase their rigidity in the vertical direction. To increase their rigidity in the horizontal direction, I epoxied braces to the arms. On my GCT the arms are 3-1/2" wide and 6" long.

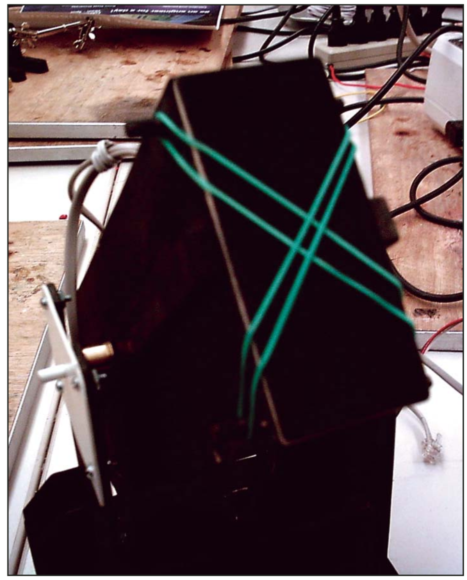


■ FIGURE 9. Gap between the GCT tube and the mount arms. The spacer is a brass lamp fixture. Normally I use nylon spacers, but I didn't have one in my junk box that fit my axle dowel. You can also use washers to fill the gap between the GCT tube and mount.

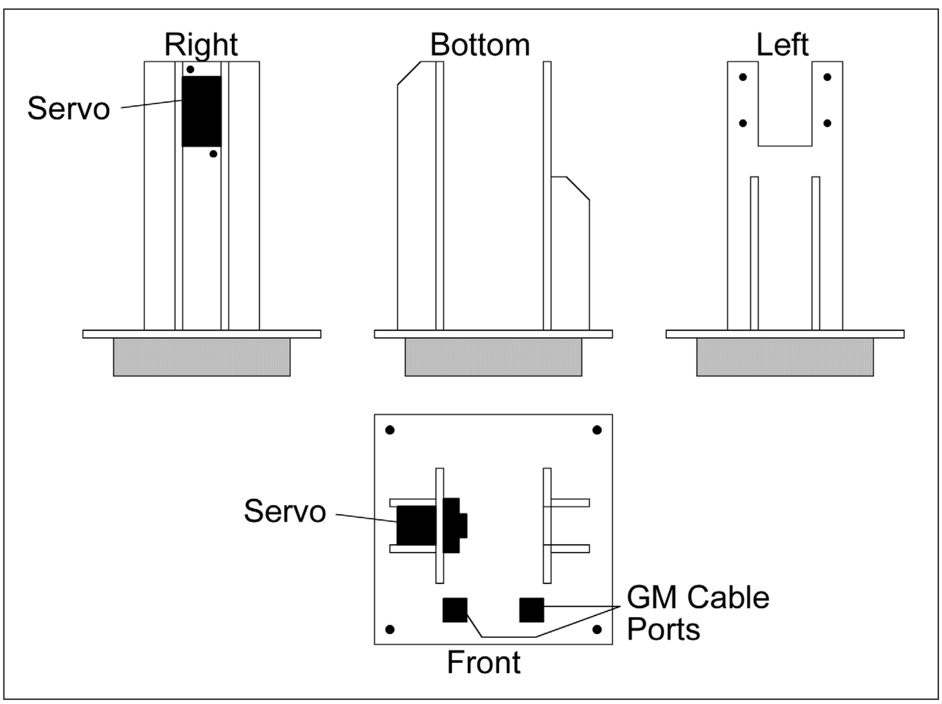
Normally, I make composite booms for my near space experiments. You can read more about how I construct them in my near space book. In my next column I'll have a short report on their construction and some tests on their breaking strength. The breaking-strength test is something I've wanted to do for a long time.

I made a rectangular cutout in one arm for the elevation servo. The servo mounts into the cutout with only two bolts that are in diagonal corners of the servo. The left arm has a much larger cutout. A thick plastic plate attaches to this cutout with four bolts. A hole drilled in the plastic plate holds the GCT tube axle dowel to the arm. By making this plate removable, it's easier to attach the CGT tube to the mount.

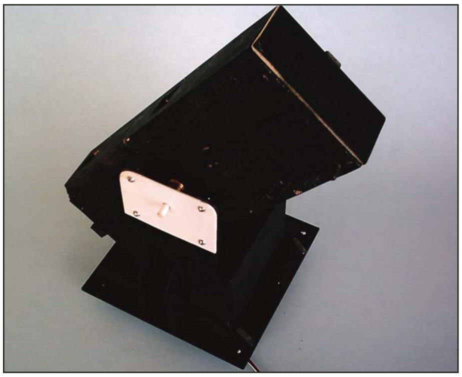
Since the elevation servo is fixed in place, I zip-tied it to its cable to mount to keep it from getting tangled up with the cables from the RM-60s. There's a hole in the mount that lets the elevation servo cable pass into the interior of the near spacecraft airframe. I find most servo cables are too short to reach the flight computer. So the elevation servo's cable was cut in two and extended in length with a wire splice. This is cheaper than purchasing a servo extension cable at the hobby shop. And I think it's more reliable since the connection is soldered together. You'll note that there's a gap between the GCT tube and the mount arms. That gap is filled with a plastic or metal tube that's cut to the correct



■ FIGURE 7. The GCT cap.



■ FIGURE 8. The GCT mount.



■ FIGURE 10. The completed GCT.

length. That tube also makes it easier to mount the GCT tube into place. Cut this tube slightly shorter than the width of the gap, since you want the GCT tube to rotate with minimum friction (see Figure 9).

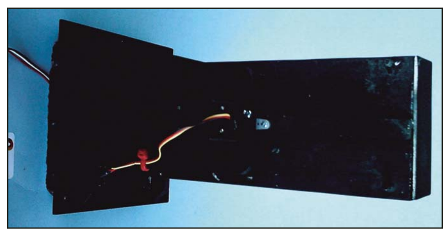
Be sure to center the elevation servo before you attach the GCT tube to it. Then slide the spacer over the axle dowel and finish by bolting the plastic plate into its arm. The GCT tube should be free to rotate from at least horizontally to vertically.

I found that the arms in my GCT mount were not as rigid as they needed to be (that's not a problem when I use my customary laminated Styrofoam). So I epoxied an additional plate over the top of the arms and near their base. Although the position of this plate prevents the GCT tube from rotating below the horizon, I don't need to make a measurement from that position during a near space mission.

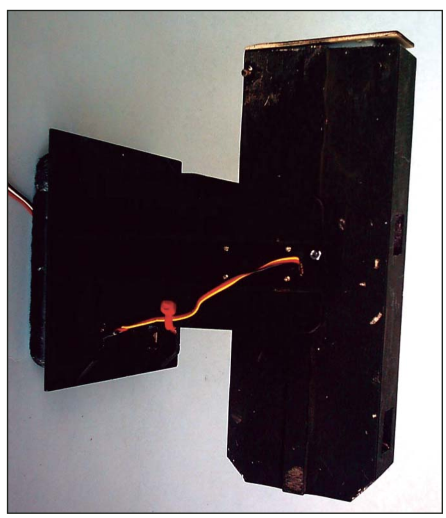
I finished the GCT mount by cutting two holes through it to allow the RM-60 serial cables to pass through and into the interior of the near spacecraft airframe. Figure 10 shows my completed GCT, and Figure 11 shows it rotated into the vertical and horizontal positions.

My next near space column will include the code needed to operate the GCT and will describe the testing I performed on it. I figure you'll have your GCT telescope done by then.

Onwards and Upwards,
Your Near Space Guide **NV**



■ FIGURE 11. These images show the GCT mount on its side because that's the way it will mount to the airframe of my near spacecraft.



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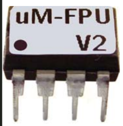

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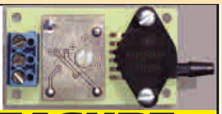

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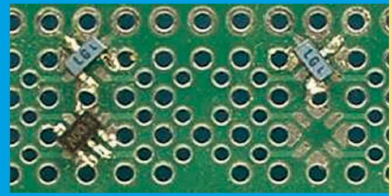

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READER FEEDBACK

Continued from page 6

As you'll see in future Design Cycle columns, I tend to lean towards making the projects I present practical and inexpensive. Sometimes, I have to resort to the more costly tools to get my idea across accurately. In the case of the 68HC908MR16, you can save $300 by using a MONO8 support device rather than the Cyclone Pro. I hope this has helped you. If there is anything I can help you with, just let me know.

Peter Best

COULDN'T RESIST

Regarding the March article on Resistors by Ward Silver ... one odd behavior of resistors that I ran into during my 28 years at Bell Labs was dR/dV. I had to build, for production, a negative resistor that worked over a range of ±100 volts and be accurate over that range to a few PPM. Long term accuracy was around ±0.01%.

There was a voltage divider that sensed the input voltage made by laser trimming thick film resistors. At first, we trimmed the resistor that saw most of the voltage. This was a disaster — the resistance changed as a function of voltage on the order of around 10 PPM. The operational theory was that the laser left a rough edge and breakdown was occurring. We then started to trim the resistor that did not see much voltage and the problem was solved.

By the way, the resistive loading of this voltage divider on the input was also canceled by the effective negative resistance of the circuit so the algorithm that trimmed the resistor network was a function of the absolute value of the sum of the large and small resistor. Great fun! Keep up the great writing!

Rick Sparber

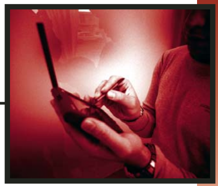
Response: Thanks for the nice comments about the article. You're exactly right — once you start caring about precision beyond 0.5%, things get "tetchy" and the third and fourth order effects start becoming significant. In HV applications, even fingerprints and drafts of air can upset a carefully calibrated divider! Balancing all of the temperature co-efficients and gradients can be a lot more work than designing the electrical part of the circuit. You probably know all about that from your history at Bell Labs.

I'm glad to have someone reading and paying attention!

Ward Silver

PATENTED PROCEDURE

Regarding Ronald Robbins' letter in the Feb. 2006 issue of N&V, anyone interested in that patent



doesn't have to be limited to the first two pages, you can view the whole patent at the patent office website: www.uspto.gov

Once there, click on Search (under the "patents" heading), then Patent Number search, and when the text box opens up just put in the number of the patent (1,745,175)

Howard Mark
Suffern, NY

FREE DIPS

I noticed the info about Diptrace. I had no idea there was a free version. I was doing a project that was too large for EagleCad and I wanted an autorouter. Diptrace did the job perfectly. It seems to be a great program for those small to medium jobs. The best part is it isn't difficult to learn like and will autoroute one layer with jumpers. The only downfall is it doesn't have any of the new pics in the library, you have to create them.

Ben Yaroch

GETTING OLDER AND BETTER

Just wanted to say that I think the magazine has gotten better and better over the years when all the industrial electronics mags that I get are getting worse. I really like the fact that I can now download an electronic version that allows me to view past issues a lot easier than digging out a paper copy. Kudos to you for all your effort and the great content of your mag ... and keep the PIC projects coming too!

Bob Stout
Milwaukee, WI

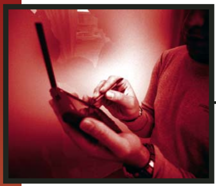
SAD "TRENCH" DIGGER

I was quite disappointed to learn that Gerard Fonte's column "In The Trenches" was discontinued. I looked forward to that column every month. It was always filled with the kind of insight that is only obtainable after having been around the block a time or two. I was even more disappointed to learn it was apparently replaced by Yet Another PIC Basic column. I realize that companies spend quite a few advertising dollars with you guys but, I'm really tired of learning new and innovative ways to blink or flash an LED or two using a PIC and PICBasic. Are these the only authors you can find? Or do you just ignore the others in favor of your large advertisers? Don't get me wrong, I mean no offense to the YAPB authors but two regular columns plus a project or two all based on PICs and PICBasic would perhaps be better served by a magazine titled PICs and Stamps rather than *Nuts & Volts*.

Glenn Hamblin
Tucson, AZ

GLAD "TRENCHES" GETS THE ... SHOVEL

I am very glad that the "In the



READER FEEDBACK

Trenches" column has been discontinued. While I thought it was well-written and very good for what it was, it was not at all congruent with the reasons I enjoy *Nuts & Volts*. I rely on the magazine for information about electronics projects and new devices/circuits. This is not, in my view, what "In the Trenches" was about — at all! Please don't let the only electronics hobby magazine in the US go under because of non-electronics material! Thanks!

Dave Wiseman

NO FUZZY LOGIC

I always thought the "fuzzball" rating system for projects was out of place in *Nuts & Volts*. The plain circles are much more appropriate. *Nut & Volts* is a great magazine and the only complaint I've ever had was the fuzzball thing and it seemed too petty for me to complain about it. But now that it's been changed, I can say "Thank You." Keep up the good work. *Nuts & Volts* just keeps getting better.

Eric R. Snow

AMP-ED UP

Excellent article by George Trinkaus on the Mag-Amp. No boring retoric, excellent easy-to-understand diagrams, top notch work. A beginner would have no trouble constructing one. In case you don't know all the angles, I use the same process in some of my positioning indicators. Figure 1 is a good enough diagram. If you secure the ferrite stick to your door, and the coil to the door frame, you can — with extreme accuracy — measure how far the door is opened. Also a tremble switch can be constructed by connecting the ferrite stick to a spring when the assembly is wiggled, a voltage change occurs. One last thing, the article specifies 115 volts, but the unit will work with voltages as low as 12, and you can build them for free!

Overall a perfect article.

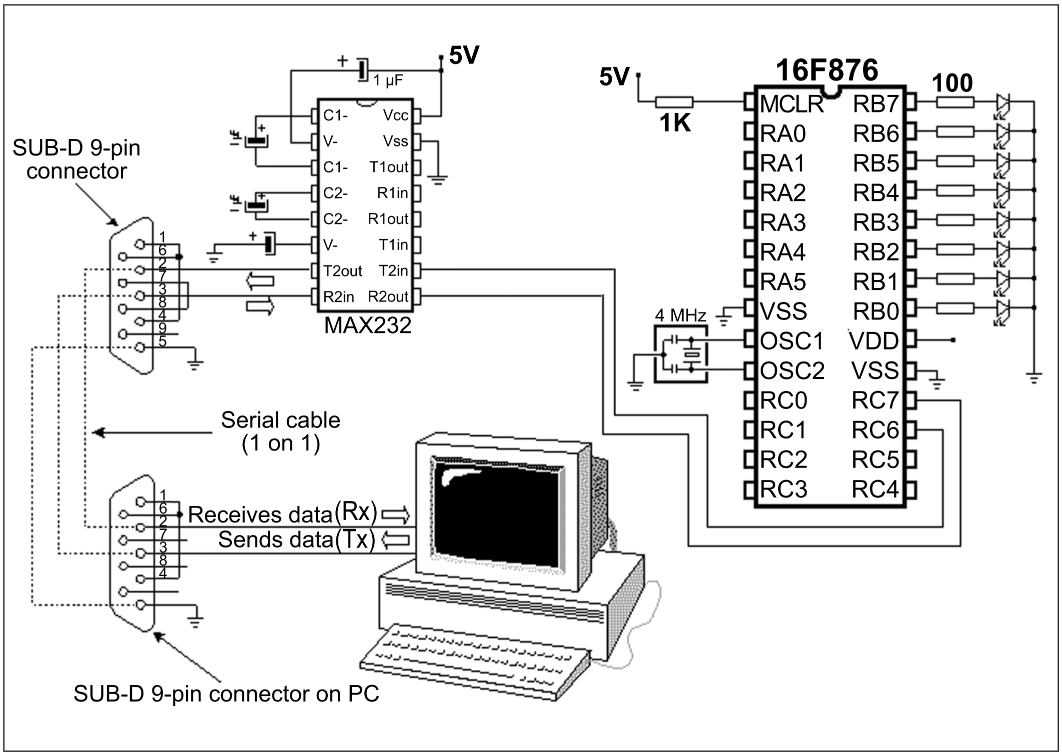
Steve Behling
South Bend, IN

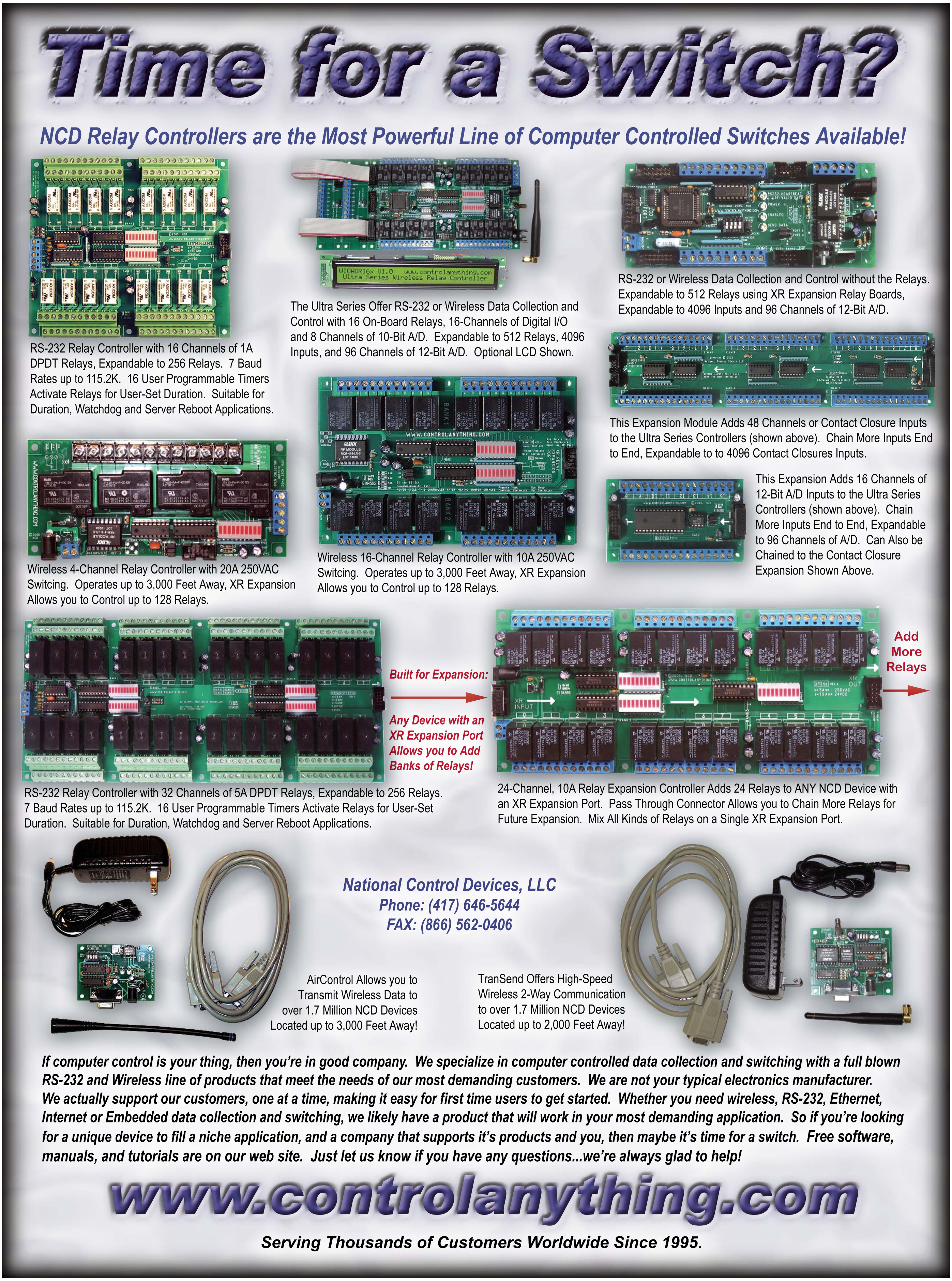
PIN PICKINS'

In my March PIC-to-PC communication article, I made a mistake in the schematic.

The C7 pin should be connected to the R2out pin of the RS232 chip and the C6 pin should be connected to the T2in pin. This is opposite of the printed schematic. A corrected schematic is shown to the right.

— Chuck Hellebuyck

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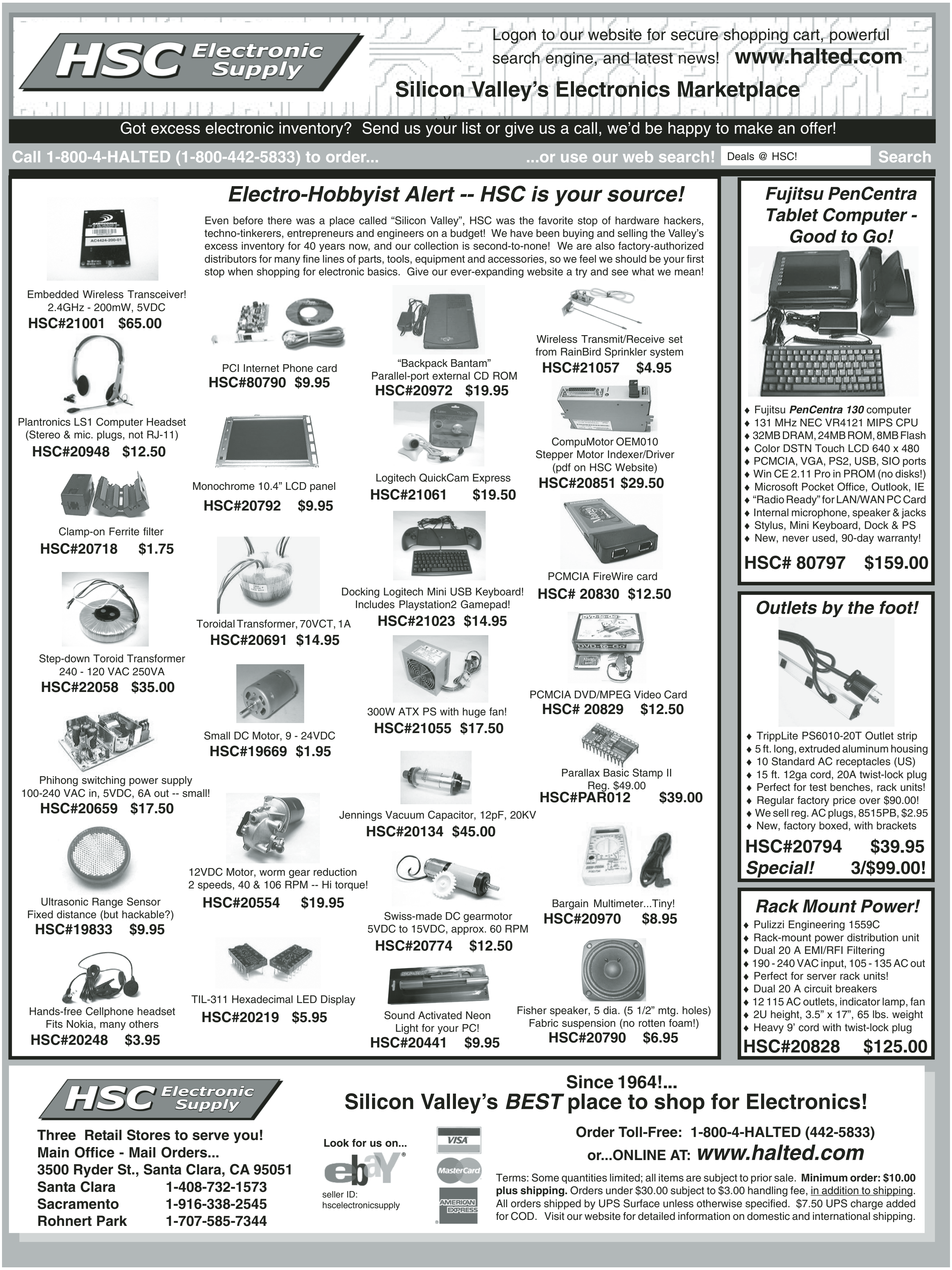
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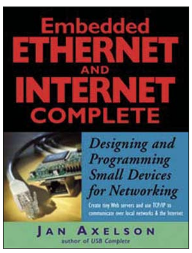
Embedded Ethernet and Internet Complete
by Jan Axelson



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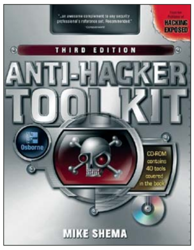
by Mike Shema



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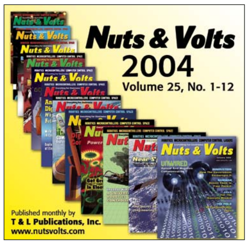
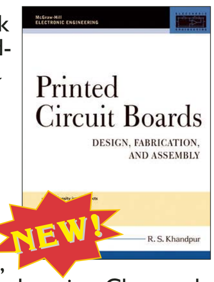


Here's some good news for *Nuts & Volts* readers! Starting with the January 2004 issue of *Nuts & Volts*, all of the issues through the 2004 calendar year are now available on a CD that can be searched, printed, and easily stored. This CD includes all of Volume 25, issues 1-12, for a total of 12 issues. The CD-Rom is PC and Mac compatible. It requires Adobe Acrobat Reader version 6 or above. Adobe Acrobat Reader version 7 is included on the disc. **$29.95**

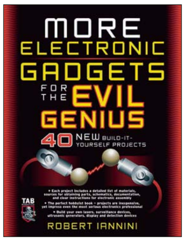
ELECTRONICS

Printed Circuit Boards
by R. S. Khandpur



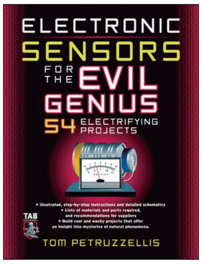
The printed circuit is the basic building block of the electronics hardware industry. This is a comprehensive, single volume self-teaching guide to the art of printed circuit board design and fabrication — covering the complete cycle of PCB creation, design, layout, fabrication, assembly, and testing. Clear and concise, *Printed Circuit Boards* leads readers through the complete cycle of PCB creation, from design, layout, fabrication, and assembly to final testing. Skirting dense mathematics, the text provides insight and guidance on design challenges brought about by the ever-increasing density of today's microelectronics. **$99.95**

MORE Electronic Gadgets for the Evil Genius
by Robert E. Iannini



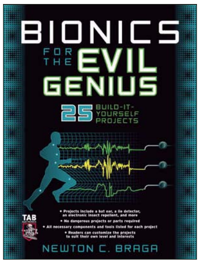
This much anticipated follow-up to the wildly popular cultclassic *Electronic Gadgets for the Evil Genius* gives basement experimenters 40 all-new projects to tinker with. Following the tried-and-true Evil Genius Series format, each project includes a detailed list of materials, sources for parts, schematics, documentation, and lots of clear, well-illustrated instructions for easy assembly. Readers will also get a quick briefing on mathematical theory and a simple explanation of operation along with enjoyable descriptions of key electronics topics. **$24.95**

Electronic Sensors for the Evil Genius — 54 Electrifying Projects
by Thomas Petruzzellis



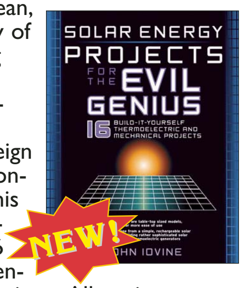
Nature meets the Evil Genius via 54 fun, safe, and inexpensive projects that allow you to explore the fascinating and often mysterious world of natural phenomena using your own home-built sensors. Each project includes a list of materials, sources for parts, schematics, and lots of clear, well-illustrated instructions. Projects include rain detector, air pressure sensor, cloud chamber, lightning detector, electronic gas sniffer, seismograph, radiation detector, and much more. **$24.95**

Bionics for the Evil Genius
by Newton C. Braga



Step into the future — (or the past, if you have a touch of Dr. Frankenstein in your soul) — with these 25 incredibly cool bionic experiments! Demonstrating how life forms can be enhanced, combined, manipulated, and measured with electronic and mechanical components, these inexpensive projects from internationally renowned electronics guru Newton Braga provide hours of fun and learning. Totally safe, *Bionics for the Evil Genius* guides you step by step through 25 complete, intriguing, yet low-cost projects developed especially for this book — including an electric fish, a bat ear, a lie detector, an electronic nerve stimulator, a panic generator, and 20 other exciting bioelectric/mechanical projects! **$24.95**

Solar Energy Projects for the Evil Genius
by John Iovine



Solar energy is a clean, inexhaustible supply of energy that is being explored more and more given the current state of our dependency on foreign oil and global environmental concerns. This is an easy, fun reference for building 16 practical and inexpensive solar energy projects. All projects are table-top sized models for ease of use and can be scaled larger if necessary. **$24.95**

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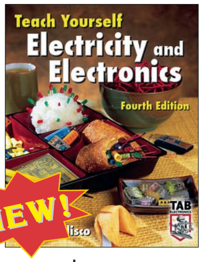
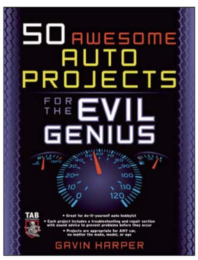
Teach Yourself Electricity and Electronics — Fourth Edition
by Stan Gibilisco



Learn the hows and whys behind basic electricity, electronics, and communications without formal training. The best combination self-teaching guide, home reference, and classroom text on electricity and electronics has been updated to deliver the latest advances. Great for preparing for amateur and commercial licensing exams, this guide has been prized by thousands of students and professionals for its uniquely thorough coverage ranging from DC and AC concepts to semiconductors and integrated circuits. **$34.95**

AUTOMOTIVE

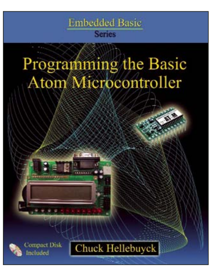
50 Awesome Auto Projects for the Evil Genius
by Gavin D J Harper



The Evil Genius format is the perfect "vehicle" for 50 incredible automotive projects that are compatible with any car, no matter what make, model, or year. Focusing on low-cost, easily obtained components, *50 Awesome Auto Projects for the Evil Genius* lists the items needed to complete each project along with a troubleshooting and repair section. **$24.95**

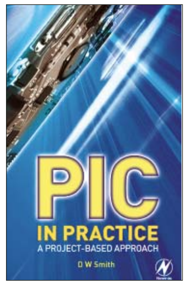
MICROCONTROLLERS

Programming the Basic Atom Microcontroller
by Chuck Hellebuyck



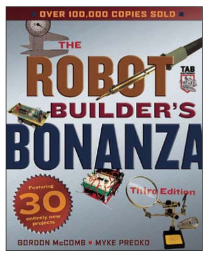
Through his unique way of making the complicated understandable, Chuck takes the reader through the inner workings of the Basic Atom by explaining the Microchip PIC Microcontroller and its roll in the Atom module. From there, Chuck explains the various PIC based Basic Atom modules and how to use the Basic Atom compiler. Chuck then delivers 13 projects the reader can build and learn from. The reader can then use this knowledge to develop their own Basic Atom projects. **$39.95**

PIC in Practice
A Project-based Approach
Second Edition
by David W. Smith



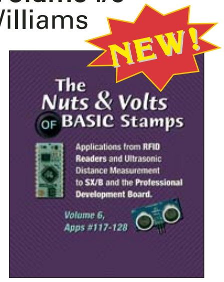
PIC in Practice is a graded course based around the practical use of the PIC microcontroller through project work. Principles are introduced gradually, through hands-on experience, enabling students to develop their understanding at their own pace. The book can be used at a variety of levels and the carefully graded projects make it ideal for colleges, schools, and universities. Newcomers to the PIC will find it a painless introduction, whilst electronics hobbyists will enjoy the practical nature of this first course in microcontrollers. **$29.95**

Robot Builder's Bonanza Third Edition
by Gordon McComb/Myke Predko



Everybody's favorite amateur robotics book is bolder and better than ever — and now features the field's "grand master" Myke Predko as the new author! Author duo McComb and Predko bring their expertise to this fully-illustrated robotics "bible" to enhance the already incomparable content on how to build — and have a universe of fun — with robots. Projects vary in complexity so everyone from novices to advanced hobbyists will find something of interest. Among the many editions, this book features 30 completely new projects! **$27.95**

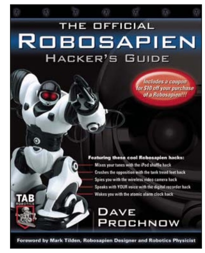
Nuts & Volts of BASIC Stamps — Volume #6
by Jon Williams



Nuts & Volts of BASIC Stamps — Volume 6 includes articles #117-128, written for 2005. Article topics consist of RFID Readers and Ultrasonic Measurement, SX/B and the Professional Development Board, the advanced MIDI receiver, programming the SX microcontroller in BASIC, mastering the MC14489 display driver, and more! The Nuts & Volts of BASIC Stamps books are a favorite Parallax technical pick and are a tremendous technical resource for all PBASIC programming projects. **$14.95**

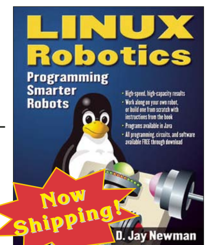
ROBOTICS

The Official Robosapien Hacker's Guide
by Dave Prochnow



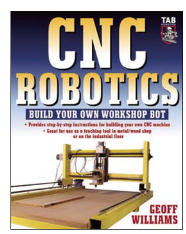
The Robosapien robot was one of the most popular hobbyist gifts of the 2004 holiday season. The brief manual accompanying the robot covered only basic movements and maneuvers — the robot's real power and potential remain undiscovered by most owners — until now! This is the official Robosapien guide — endorsed by WowWee (the manufacturer) and Mark Tilden (the designer). This timely book covers all the possible design additions, programming possibilities, and "hacks"not found anywhere else. **$24.95**

Linux Robotics
by D. Jay Newman



If you want your robot to have more brains than microcontrollers can deliver — if you want a truly intelligent, high-capability robot — everything you need is right here. *Linux Robotics* gives you step-by-step directions for "Zeppo," a super-smart, single-board-powered robot that can be built by any hobbyist. You also get complete instructions for incorporating Linux single boards into your own unique robotic designs. No programming experience is required. This book includes access to all the downloadable programs you need, plus complete training in doing original programming. **$34.95**

CNC Robotics
by Geoff Williams



Written by an accomplished workshop bot designer/builder, *CNC Robotics* gives you step-by-step, illustrated directions for designing, constructing, and testing a fully functional CNC robot that saves you 80% of the price of an off-the-shelf bot — and can be customized to suit your purposes exactly because you designed it. **$34.95**

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TECH FORUM

This is a READER-TO-READER Column.

All questions *AND* answers are submitted by *Nuts & Volts* readers and are intended to promote the exchange of ideas and provide assistance for solving problems of a technical nature. Questions are subject to editing and will be published on a space available basis if deemed suitable by the publisher. Answers are submitted by readers and NO GUARANTEES WHATSOEVER are made by the publisher. The implementation of any answer printed in this column may require varying degrees of technical experience and should only be attempted by qualified individuals. Always use common sense and good judgement!

All questions and answers should be sent by email to forum@nutsvolts.com All *diagrams should be computer generated and sent with your submission as an attachment.*

QUESTIONS

To be considered, all questions should relate to one or more of the following:

1. Circuit Design
2. Electronic Theory
3. Problem Solving
4. Other Similar Topics

■ Be brief but include all pertinent information. If no one knows what you're asking, you won't get any response (and we probably won't print it either).

■ Include your Name, Address, Phone Number, and email. Only your Name, City, and State will be published with the question, but we may need to contact you.

■ No questions will be accepted that offer equipment for sale or equipment wanted to buy.

■ Selected questions will be printed one time on a space available basis.

■ Questions are subject to editing.

ANSWERS

■ Include in the subject line of your email, the question number that appears directly below the question you are responding to.

■ Payment of $25.00 will be sent if your answer is printed. Be sure to include your mailing address or we cannot send payment.

■ Only your Name, City, and State, will be printed, unless you say otherwise. If you want your email address included, indicate to that effect.

■ Comments regarding answers printed in this column may be printed in the Reader Feedback section if space allows.

>>> QUESTIONS

I am trying to remake a 3.5 x 5 calculator, with a 4mm x 6mm hole in the center to install a push button in-between the digital readout and the buttons. What parts do I need to make a circuit board, calculator, digital readout, etc.? Any information would be greatly appreciated.

#5061 *Brent Dickson*
via email

I need a log-scale level indicator using bipolar transistors.

Without using an integrated-circuit comparator, or an op-amp, there should be a method to make a bipolar transistor-based five-LED output VU or level display for an audio amp. In this case, though, I want the display to take its input at the pre-amp level signal as it is applied to a 10K volume pot, so that it indicates the level of input prior to the volume control, and so is independent of the volume control. The response should be logarithmic. I know how to do this with comparators and op-amps, but not using only bipolar transistors as the log generator and LED drivers. I'd like to see a minimal parts-count solution with the applicable math. The power-amplifier in question (TEA-2025) has a +12 VDC-to-ground supply, an input impedance of 30K, and gain of 45 db, so the applicable pre-amp level signal is derived from those parameters — having no way to measure it directly — and is fed from the wiper of the 10K volume control. An interesting old-school problem.

#5062 *Stephen Clanahan*
Coalinga, CA

I would like to monitor the voltage and current of my solar electric system. The array open circuit voltage is 270 VDC, under load at 230 VDC, and current is at 11 amps. Can someone suggest an input circuit which provides isolation and protection for the PIC16F688 I plan to use?

#5063 *Steve Yang*
Sunnyvale, CA

How are fireworks controlled in the big July 4th shows? They must be computer controlled because the rockets, roman candles, etc., go off at closely spaced times. If so, what is the interface between the fuses and the computer; and, how are the signals distributed?

#5064 *Ronald Rosien*
via email

I have a rear view camera from a 2004 Honda MDX. Other than the power and ground connections, there are leads for video, camera ground, shutter, and camera adap.(?). Placing an oscilloscope across the video and camera ground leads gives me hori-

zontal blanking and sync pulses but no video. I have placed a load resistor (75 ohms) across the video and camera ground terminals. Also, I have tried connecting five volts (through a 10 ohm limiting resistor) to the shutter and the camera adap. leads; but I still cannot see video information. Is there some type of a circuit I need to build in order to have the camera operate?

#5065 *Doug Poray*
Jackson, NJ

>>>> ANSWERS

[#4062 - April 2006]

I recently purchased a Flash card player. The power unit that came with it is an AC to DC supply rated at 5V @ 1.5A. While playing, it actually is using 620 mA.

I wanted to connect to 12V automobile power by replacing the AC to DC unit with a 12V to 5V. I measured the amperage and it too was 600 mA. The problem now is that the 12V to 5V regulator overheats and eventually will fail.

If you are using a one amp voltage regulator in a TO-220 package without a heatsink, the thermal resistance junction to ambient is 50 degrees C per watt. The 12 volts is actually 13.8 volts when the motor is running, so the voltage drop across the regulator is: 13.8-5=8.8 volts. The power dissipation is: 8.8*.6 = 5.28 watts. Multiplying by the thermal resistance, the junction temperature of the IC is 50*5.28 = 264 degrees C, which is way over the allowed temperature.

The solution is to use a heatsink. A half-brick heatsink (Wakefield 528-45AB) is about five square inches and is rated 8.6 degrees C per watt. The TO-220 package is rated 2.5 degrees C per watt junction to case. If an insulator is used, it is about 0.1 degrees C per watt. The total thermal resistance in this case is: 2.5+0.1+8.6 = 11.2 degrees C per watt. Now the junction temperature is 5.28 watts * 11.2 = 59 degrees C, which is within the rating of the IC.

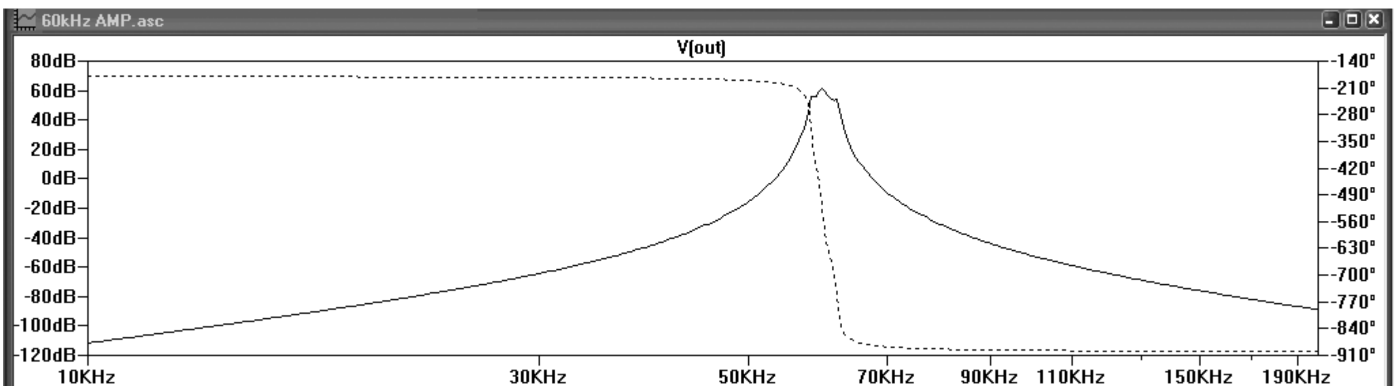
Russell Kincaid
Milford, NH

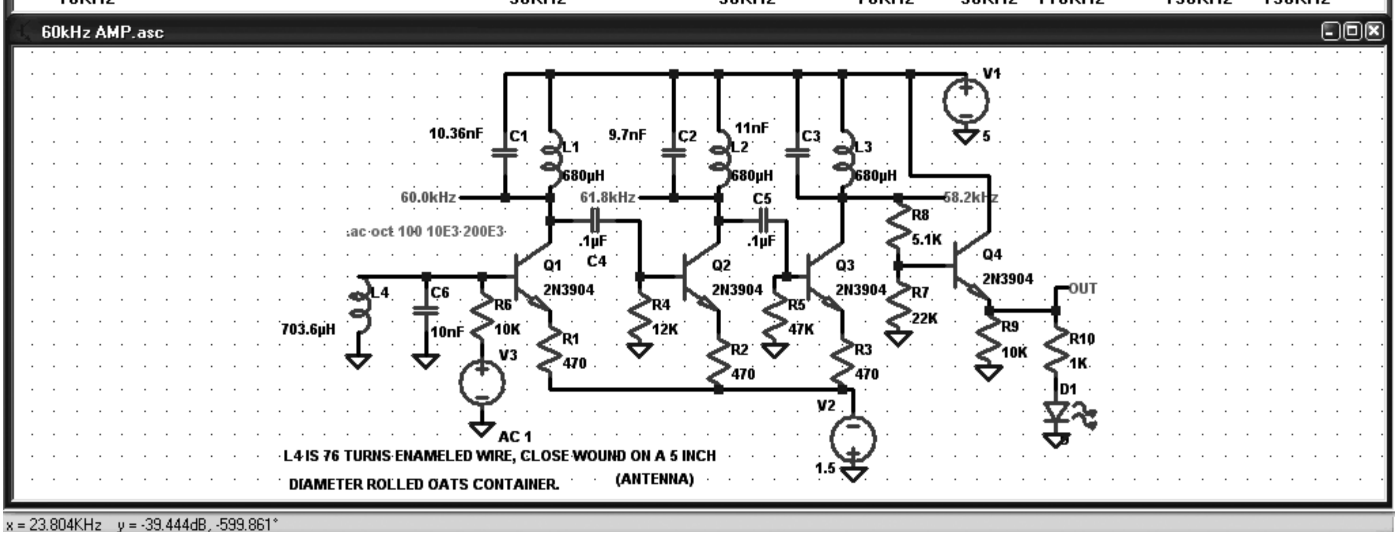
[#2062 - February 2006] ***(Revisited)***

I am looking for an easy build-it-yourself receiver to pick up the 60 kHz signal from WWVB. I live in the Pittsburgh, PA area and I have a few atomic clocks that never receive the updates. I would like to hear or at least see the pulses via an LED indicator just to see if the signal is really there.

I have not built this receiver, but it simulates okay. The gain is 60 dB so you will have to be careful that it does not oscillate. Don't make it too compact; keep the input and output separated. Place the inductors to be at right angles to each other to minimize any coupling. Use lots of power supply bypassing. The antenna is a loop, tuned to 60 kHz. The LED should change brightness with the modulation on the signal.

Russell Kincaid
Milford, NH





[#4064 - April 2006]

I built a device that signals my mother from inside the house when the mail has come, so she does not have to watch for the postal carrier. Now, I want to take it a bit further and connect the device to the TV and have it send both a message and a video flag in one corner while she watches TV. Can someone help or point me to a device that can do this? I would welcome any ideas.

#1 Decade Engineering sells an On-Screen-Display that can do what you want. You would have to connect a microcontroller to it and place it in-line between your CABLE/SAT/VCR and your TV's video jacks. Here is a link to their website: **www.decadenet.com/bob3/bob3.html**

Daryl Rictor
via email

#2 That sounds like a great project. May I suggest the SX-Video OSD module. This module will overlay text on the TV screen.

You will need a BASIC Stamp or some controller that can output serial data at 2400 baud to communicate with the module.You can purchase the module directly from **www.sxvm.com** or from Parallax Inc. item # 30015.

Terry Hitt
via email

[#4063 - April 2006]

I need a circuit to convert s-video to composite video.

#1 It is possible to construct an s-video to composite converter with just a couple connectors and a capacitor. It is not an ideal converter because the signal impedances and levels aren't matched perfectly, but it works well in most cases. Just cut up an s-video cable, and connect the Y ground and C ground to the outer ground ring of an RCA connector. Then wire one end of a 470 pf capacitor to the C pin and the other end of the capacitor to the Y pin. Then wire the Y pin to the center pin of the RCA connector. Looking into the end of a male s-video cable with the plastic key pin up, the pins are Y ground, Y, C, and C ground clockwise around the connector. If this is for a computer and your cable has more than four pins — as some video card output cables do — it is not a standard pinout and you will need to look up the pinout for your video card to find the positions of the appropriate pins.

Carl D. Smith Jr.
Fargo, ND

Female Male

SEVEN PIN S-Video MINI-DIN

Pin	Name	Description
1	GND	Ground (Y)
2	GND	Ground (C)
3	Y	Intensity (Luminance)
4	C	Color (Chrominance)
5	-	-
6	V	Composite Video
7	VGND	Composite Ground

#2 If you have a seven pin s-video source, the composite signal is already there. Pin 6 carries the composite video and pin 7 is the ground.If you have a four pin s-video, you can try an inexpensive converter, such as the one Hometech Solutions sells ($4.95): **www.hometech.com/video/svconv.html** (Part #GC-AVF2RF).

Daryl Rictor
via email

[#4066 - April 2006]

I would like to hear my TV audio at a remote location through external speakers or earphones. My TVs have audio outlets in the back, but no audio is coming out of them.

First, make sure those RCA audio jacks are not INPUTS. They should be labeled with the words "IN" (for input from a VCR or DVD player) and "OUT" (to send to a receiver/external amp). Consult your User Manual — it should tell you.

If the RCA jacks are indeed OUTPUTS, access the "Audio Setup" option of the TV's menu and ensure the "Audio Output" option is enabled. Then, connect SHIELDED RCA cables from those jacks to the AUX inputs of your remote receiver/amp, adjust the volume of the remote amp to taste, and enjoy.

However, if those jacks are INPUTS only, it means you'll have to tap the audio directly from across the TV speakers. This circuit works well and provides isolation between the source speaker and the remote receiver/amp:

speaker "+" — C — R —> to
RCA plug center pin

speaker "-" — C —> to
RCA plug outer shield

The capacitors "C" are .1 µF polyester units, rated at 50 VDC minimum. The resistor (R) is a 1K ohm, 1/2 watt unit. The components can be directly soldered to the speaker terminals and keep the leads AS SHORT AS POSSIBLE. Use SHIELDED AUDIO CABLE from the RCA plug to the components and cover the components with heat shrink or electrical tape. Make sure there are NO SHORTS between the capacitors and resistor AND no shorts between all components and any exposed metal part of the TV chassis.

Run the RCA plugs to the AUX input of the remote receiver/amp and set the REMOTE amp's volume to MINIMUM. Turn on the TV and adjust its volume to BARELY AUDIBLE. At this time, turn on the remote amp and adjust its volume to the desired level. NOTE: The audio quality WILL NOT be that great and you may hear some 60 Hz "background buzz." However, this is to be expected in this setup.

Finally, for "crystal clear" remote audio, assuming the TV's RCA jacks are not outputs, get a cheap Hi-Fi VCR and feed your cable-TV's input to it. Couple the VCR's audio out RCA jacks to the AUX input of the remote receiver/amp. When you want to remotely listen to the TV station's audio, tune the VCR to that station and enjoy!

Ken Simmons
Auburn, WA

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AD INDEX

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Model	CSI3644A	CSI3645A	CSI3646A
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DC Current	5A	3A	1.5A
Power (max)	90W	108W	108W

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Input Power	0-150W	0-300W

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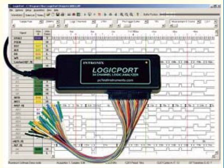

Item# LOGICPORT

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- •Sine,Triangle,Square,Pulse,Ramp, Slewed Sine Waveform
- •Sync. Out (TTL Square Waveform)
- •Accuracy: ±5% of Full Scale to 200KHz, ±8% of Full Scale from 200KHz-2MHz
- •Sweep Function
- •VCG Input

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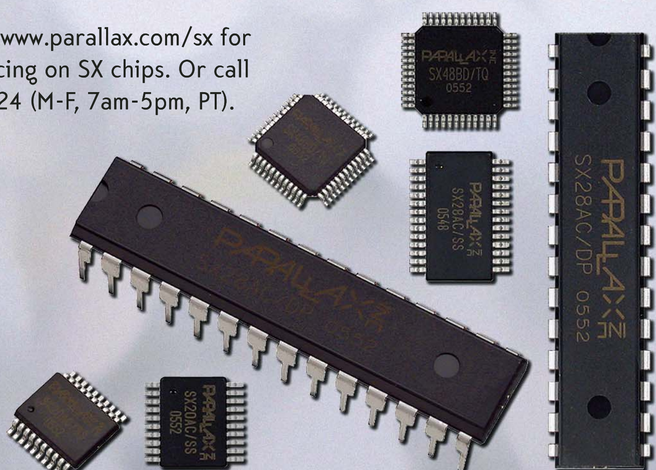
SX Chips now packaged exclusively by Parallax, Inc.

Parallax and Ubicom have formed an agreement in which Parallax will now be the exclusive supplier of the SX microcontroller. Part numbers ending in "-G" are RoHS compliant (lead free).

SX CHIP OVERVIEW

Part #	Pins	I/O	EE/Flash	RAM
SX20AC/SS	20	12	2K bytes	137 bytes
SX20AC/SS-G	20	12	2K bytes	137 bytes
SX28AC/DP	28	20	2K bytes	136 bytes
SX28AC/DP-G	28	20	2K bytes	136 bytes
SX28AC/SS	28	20	2K bytes	136 bytes
SX28AC/SS-G	28	20	2K bytes	136 bytes
SX48BD	48	36	4k x 12 words	262 bytes
SX48BD-G	48	36	4k x 12 words	262 bytes

Visit our web site at www.parallax.com/sx for more details and pricing on SX chips. Or call toll-free 888-512-1024 (M-F, 7am-5pm, PT).



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Enter to win the 2006/07 SX Design Contest!

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Use an SX Chip in your design and you could win! Parallax is holding an SX Design Contest, and you are invited to enter. All SX Projects will be judged according to: appropriateness of the SX in the design, originality, professionalism, and practicality. Complete judging criteria and contest rules can be found online.

Please Note: This contest is specifically for the SX chip and not BASIC Stamp modules with the SX chip.

Last day to obtain a Contest Project Number is September 01, 2006.

All Completed Projects are due to Parallax by January 09, 2007

Please see our website at parallax.com/sx for details and official contest rules and to obtain a Project Number.